UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 647

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. ▼ May 3, 1918

THE ARGENTINE ANT IN RELATION TO CITRUS GROVES

By

J. R. HORTON, Scientific Assistant, Tropical and Subtropical Fruit Insect Investigations

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By J. R. HORTON, *Scientific Assistant, Tropical and Subtropical Fruit Insect Investigations.*[2]

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INTRODUCTION.

The Argentine ant (*Iridomyrmex humilis* Mayr) is a native of tropical America, occurring in Argentina, Brazil, Chile, and Uruguay. It was first introduced into the United States at New Orleans about 30 years ago and was fairly numerous in parts of that city as early as 1891.[3] A few years later it had become established thoroughly in and around New Orleans and was causing great annoyance as a household, garden, and field pest. Early it was carried to California, where it has become established widely. It is especially numerous in parts of the citrus districts of Los Angeles and Riverside Counties and in the city of Los Angeles and occurs as far north as San Francisco and as far south as San Diego.

[1] For a discussion of other phases of the Argentine ant problem see Department of Agriculture Bulletin No. 377, by E. R. Barber, entitled "The Argentine Ant: Distribution and Control in the United States."

[2] Transferred to Cereal and Forage Insect Investigations, Oct. 1, 1917.

[3] Foster, Ed. The introduction of *Iridomyrmex humilis* into New Orleans. *In* Jour. Econ. Ent., v. 1, p. 289–293. 1908.

NOTE.—This bulletin is of especial interest to citrus growers in the southeastern States and generally to the public in that section.

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The Argentine ant has been the subject of special study by this bureau for several years, more particularly as to its activity as a house pest, but also as to its general economy in relation to garden, orchard, and field cultures. The facts secured in the investigations[1] prior to 1913 indicated a very important injurious relationship of this ant to citrus culture in Louisiana. As a result of this apparent condition and in response to numerous complaints of injury to citrus trees occasioned directly and indirectly by this ant, a special investigation was instituted in 1913 under the supervision of Mr. C. L. Marlatt, Assistant Chief of the Bureau of Entomology, to determine the exact economic importance of the ant as a citrus pest and to devise effective means of preventing damage in citrus orchards.

GENERAL BELIEF AS TO DAMAGE TO ORANGE TREES.

It has been recognized generally that a few species of ants may injure orchard and other crops either directly, by feeding on plant parts, or indirectly, through their symbiotic relations with scale insects and aphids.

The important features of the activities of ants toward certain scales and aphids, viz., soliciting "honeydew" excretion from them, carrying them about, constructing shelters over them, and combating their enemies, were pointed out more than a century ago by Pierre Huber,[2] some of whose observations were made upon orange-infesting species. Huber, however, makes no mention of injury caused to orange trees by these habits.

Direct injury by ants, so severe as to cause the death of the trees in orange, cacao, coffee, and cotton plantations in the West Indies, is cited by the French historian Robin,[3] contemporaneous with Huber. Robin probably referred to leaf-cutting ants, *Atta* spp., several species of which destroy trees in tropical America by defoliation.

Although the habits of ants in relation to plants and plant pests have been studied by many observers since these early writers, extreme views as to damage to orchard trees by ants, especially through the fostering of insect pests, have developed only since the Argentine ant became established thoroughly in southern Louisiana. This ant made the greatest impression upon people by its unusual abundance and aggressiveness, and became the subject of study by many laymen as well as entomologists. Interest in ants, especially as orchard

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[1] Titus, E. G. Report on the "New Orleans" Ant. U. S. Dept. Agr. Bur. Ent. Bul. 52. 1905.

Newell, Wilmon, and Barber, T. C. The Argentine Ant. U. S. Dept. Agr. Bur. Ent. Bul. 122, 1913.

[2] Huber, Jean Pierre. Recherches sur les Moeurs des Fourmis Indigènes. Paris, 1810.

[3] Robin, C[laude] C. Voyages dans l'Interieur de la Louisiane . . . 1802–1807, Tome I, p. 215. Paris, 1807.

pests, as indicated by the number of titles on this subject appearing in entomological literature, has increased greatly throughout the world in the past 10 years.

The principal convictions which had arisen, on the influence of the Argentine ant on citrus fruit trees in Louisiana, are expressed in the writings of Dr. Titus[1] and Messrs. Newell and Barber.[2] Titus states, substantially, that the ants aid in the distribution of aphids and scale insects on citrus and other trees, remove young scales to new territory, establish colonies of certain species, and appear to have become caretakers for all kinds of scales and plant-lice.

Newell and Barber, in addition to expressing the belief that the ants shelter and protect scale insects, aphids, and white flies, and establish them upon other plants, are of the opinion that it is in the orange groves that this ant has inflicted probably the most serious injury. They note that ant invasion is followed by so rapid an increase of scale insects that, unless prompt measures are taken against the ants, the second year of infestation shows a severe reduction in the crop, the third year almost complete loss, and the fourth or fifth year witnesses the death of many of the trees. These authors state further that the ants are particularly severe in their attacks upon the blossoms of the orange.

The opinion of the Louisiana orange growers themselves on this subject may be summarized from the answers received to inquiries made and submitted in 1914 as to whether the ant injures the trees and in what ways. Of those growers replying to the question, about 61 per cent believed it to be injurious, 33 per cent stated that they did not know, and about 6 per cent believed that it was not injurious. The prevailing beliefs as to the nature of the injury were, (1) that it prevents bearing, (2) destroys blossoms and roots, (3) eats feeder roots, (4) destroys the fruit, (5) takes the sap out of the new growth, (6) causes the death of limbs by traveling continuously over the same spot, and (7) injures the bloom, causing the oranges to drop. It was believed also that the ants increase, disseminate, and protect scale insects and drive out lady-beetles. One answer, however, was to the effect that the ants are beneficial because they destroy other insects. It was generally agreed that the ant causes most severe injury to the orange trees, resulting in a complete loss of crop and culminating in the death of the trees.

A preliminary survey of the orange orchards of Louisiana made it plain that many of them were suffering from some undetermined noxious influences. The trees were, as a rule, undersized, poorly shaped, lacking in the abundance of clear, dark green foliage which

[1] Op. cit., p. 79–84. [2] Op. cit.

characterizes the healthy orange tree, and production was far below the standard for trees of their average age. During the blossoming period the flowers were often somewhat too numerous and conspicuous, a condition which characterizes a "sick" tree, and dying and dead trees were numerous throughout the district.

The apparent cause of the diseased condition of the trees was often traced to heavy infestations by scale insects and white flies, but obviously, in some cases, other factors contributed to this condition. Many orchards not invaded by ants exhibited the same symptoms as those overrun by ants. Manifestly, the amount of injury done by the ant must be distinguished from that due to other causes, and this involves a knowledge of the general conditions characterizing citrus culture in Louisiana.

The investigation therefore was planned to cover, first, a thorough study of the habits of the Argentine ant in relation to orange trees, and, second, a study of the cultural practices and other conditions which might affect the successful raising of oranges in Louisiana. An experiment in the reclamation of an ant-invaded and practically abandoned orchard was conducted to determine what might be done in the way of making such orchards profitable. The problem of ant destruction and control in the orchards was taken up at the beginning of the investigation and continued throughout its course.

GENERAL ACCOUNT OF ORANGE CULTURE IN LOUISIANA.

Louisiana is, perhaps, the oldest citrus-producing State in the Union. Orange trees have been cultivated there for at least 200 years and, perhaps, longer, at least one introduction having been made from Cape Haitien (Cap Francois), Santo Domingo, by the original French concessionaires, who arrived in Louisiana in 1718,[1] and it is probable that citrus trees had been grown there by the Spanish colonists previous to this introduction.

During the long period that has elapsed since this introduction orange trees have suffered occasionally from severe freezes, and several times have been killed to the ground. Freezes of this extreme sort, occurring in the period from about 1718 to 1806, are mentioned by Le Page du Pratz,[2] Robin,[3] and several other writers. Similar killing freezes have occurred during the past century, one, in 1835, killing every orange tree from the shores of the Atlantic to the Mississippi;[4] others, the last one of which at least was equally dis-

[1] Le Page du Pratz. The History of Louisiana. Translated from the French of M. Le Page du Pratz, v. 2, p. 17–18. London, 1763.

[2] Op. cit., v. 2, p. 17.

[3] Op. cit., p. 474.

[4] De Bow, J. D. B. *In* Review, v. 18, p. 609. New Orleans, 1855.

astrous, occurred in 1886,[1] 1895, and 1899.[2] These freezes had the effect largely to discourage the commercial growing of oranges in Louisiana. Many of the succeeding citrus orchards consisted mainly of volunteer sprouts from the old roots allowed to grow at will without care or culture. After the later freezes considerable nursery stock, untrue to name and poor in quality, was imported into the State. The present citrus industry of Louisiana has developed since the great freeze of 1899, and all the trees now growing have sprung from old roots or have been planted during or subsequent to that year.

Considerable damage also has been sustained by some of the orange orchards from floods due to excessive rainfall and high water and from tidal waves blown in from the Gulf of Mexico and the Barataria section by hurricanes and lesser storms.[3] An orange grower informed the writer that such storms had, by washing salt water from the Gulf over the orange trees on the left bank of the river below Pointe a la Hache, caused almost complete abandonment of orange growing in that section. Of the 8 or 10 severe storms of this nature, occurring in the past several years, those of 1893 and 1915 probably caused the greatest damage to citrus orchards. The storm of 1893 was followed by a tidal wave which "engulfed everything before it,"[4] the water sweeping over the orange groves to a depth of from 3 to 5 feet or more in places, and remaining there for several days. While the present investigation was still in progress there occurred the most severe hurricane of all, that of September 29, 1915. Besides destroying more than 90 per cent of the entire orange crop of the State, and extensively damaging many of the trees by stripping off their leaves and breaking branches, this storm blew water in, at first directly from the Gulf and river; and, on its recurve, brought brackish water, laden with millions of tons of rushes from the Barataria swamps. The water remained about the trees in parts of the orange section for several days, and the rushes were deposited from 3 to 4 feet deep on the ground, many of the trees being laden with them. It is difficult, at present, to estimate the damage that will result from this storm to trees not actually killed; but one way in which it will manifest itself will be in the increased number of poorly formed trees due to killing of the branches by defoliation.

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[1] Stubbs, W. C., and Morgan, H. A. The Orange and Other Citrus Fruits. La. St. Agr. Exp. Sta. Special Bul., p. 5, 1893.

[2] Records of the freezes of 1886, 1895, and 1899 are contained in U. S. Weather Bureau reports.

[3] See Humphreys, Capt. A. A., and Abbot, Lieut. H. L., "Report upon the Physics and Hydraulics of the Mississippi River," Washington, 1861, for a record of the earlier floods along the lower Mississippi; and Cline, Dr. I. M., in articles in the U. S. Dept. Agr. Weather Bur. Buls. M (1904) and Y (1913), by H. C. Frankenfield.

[4] Garriott, E. B. West India Hurricanes. U. S. Dept. Agr. Weather Bur. Bul. H, p. 40. Washington, 1900.

The principal source of damage to the present citrus plantings is, however, neglect of a proper routine of nursery and orchard practice, including control of insect pests. Pruning in the nursery to produce symmetrical trees with the greatest possible production of fruit-bearing wood has been neglected. Later, when planted in the orchard, branches of various sizes are allowed to die from one cause or another, often from scale insects, and the dead wood removed, leaving a misshapen tree. The trees are nearly always planted too close. Owing to the shallowness of the soil [1] the orange roots must spread to a great distance close to the surface, those of the different rows thus meeting and forming a network over the entire orchard. The branches of the various trees in the row also interlace in many cases, resulting in comparatively puny and undersized trees and low production. Furthermore, it is often impossible, at least always difficult, to get about in the orchard to give it the proper cultivation and spraying, and in cultivating the bark frequently is bruised and branches of varying sizes are broken.

Cultivation, fertilization, and spraying are neglected very often or practiced only intermittently. As stated by their owners, about 38 per cent of the orchards are not cultivated at all, the weeds in many of them growing almost as high as the trees. About 10 per cent of the orange groves receive such cultivation as is necessary for the raising of vegetables, which are grown between the rows.

Several classes of fertilizer are used, regularly by some, and intermittently by others. The chief kinds used are cotton seed, either meal or whole, commercial mixed fertilizer, stable manure, and shrimp hulls; sometimes two or more of these are used together. Approximately 37 per cent of the orchards, however, had received no fertilization of any kind for several years. A considerable proportion of the orchards, about 30 per cent, are sown with a cover crop, generally cowpeas.

No standard program of controlling insect pests has been followed, except by a very few of the more progressive growers. According to reports received from 97 per cent of the orange growers of the State, spraying against scale insects, the white fly, and the rust mite has been practiced at one time or another in the last five years by only 15 per cent of those who reported. Some of those who sprayed made only 1 application a year, others as high as 5, and 11 different combinations of insecticides had been used with an

[1] The water table in Plaquemines Parish, where over 90 per cent of the citrus fruit of Louisiana is produced, lies from 1 foot beneath the surface in some orchards to 7 feet in others, but the average depth throughout the parish is only $2\frac{3}{4}$ feet. Draining usually is accomplished by open ditches, from 1 to $2\frac{1}{2}$ feet deep and from 2 to 3 feet wide at the top, leading to an outfall canal, which connects with a bayou of the swamps. In some cases there is a pump, propelled by a gas engine, to hasten the outflow and care for exceptionally heavy rains; and around some groves rear and side levees are constructed. About 40 per cent of the groves, however, have no drainage system.

array of spraying machinery that was even more diversified and inefficient than the insecticides. About 6.5 per cent of those who reported had at one time or another treated for the white fly by spraying the spores of the three or four entomophagous fungi known to attack this insect.

After becoming familiar with the relations of the Argentine ant to the trees and the infesting scale and other insects, the history of the plantings, the natural conditions, and the widespread neglect of good cultural practices, one is forced to conclude that the latter are factors of much greater importance than the ant as causes of damage to and the destruction of citrus trees in Louisiana. The progressive decrease of production occurring in the last five or six years,[1] as well as most of the more severe forms of injury to the trees, is due to a combination of the causes here enumerated. The several armored scales, the white fly, and the rust mite, which, of course, cause much injury to the trees, can be controlled without difficulty in the presence of the ants and regardless of them, as will be shown later. It is possible that under new conditions the citrus mealybug and the fluted scale may become serious pests in the orange groves of Louisiana. The mealybug might become abundant on trees kept clean of other scales and white flies or in the event of a scourge overtaking its natural enemies. The fluted scale, from all reports, already has become a serious pest to ornamental orange and other trees in the city of New Orleans since the present investigation was discontinued, and later may be expected to infest the orange groves.

DISTRIBUTION OF THE ANT IN THE ORANGE GROVES OF THE UNITED STATES.

LOUISIANA.

Data on the distribution of the Argentine ant in the orange groves of Louisiana have been received from the owners or by actual inspection of 99 per cent of the groves of the State. The ants are present in 26.1 per cent, or about one-fourth of these groves. On the west bank of the Mississippi River, from McDonoughville to Home Place, in Plaquemines Parish, the ants are in 62.9 per cent of the groves; from Home Place to Buras, exclusive of the latter, they are present in 77.3 per cent of the orchards; from Buras to Venice, inclusive, they have invaded only 5.5 per cent. On the east bank of the river, in Orleans, St. Bernard, and Plaquemines Parishes, 23.8 per cent of the orchards between New Orleans and Olga, La., are infested with the Argentine ant. Over 95 per cent of the citrus

[1] The actual reduction of the orange crop of Louisiana, based on complete data as to number of bearing trees and amounts of greatest and last (i. e., 1914) crops of 80 per cent of the bearing trees of the State, is 36.8 per cent. The present production, in other words, is only 63.2 per cent of what the orange trees have proved themselves capable of producing.

fruits of the State are produced in these three parishes, so the above figures give an accurate idea of the proportion of the orange groves that come under the influence of the ants. The ant has not yet gained an entrance into any of the seedling orange groves of Cameron Parish.

CALIFORNIA.

In California the ants are present in a considerable number of the groves at Riverside, Corona, Uplands, Duarte, Monrovia, Sierra Madre, Alhambra, San Marino, South Pasadena, Pasadena, and Altadena. They have gained a foothold in one spot in the town of Pomona, but have not yet been reported in any of the orange groves. When they do arrive there, however, they undoubtedly will bring the mealybug into great prominence, as a minor outbreak occurred during the summer of 1916, and conditions are the same there as at Alhambra. They are distributed pretty thoroughly throughout parts of the cities of Los Angeles and Pasadena. In Ventura County they infest some of the groves at Santa Paula and occur in several groves in one block at Fillmore. They have every appearance of having been introduced into this section within the last three or four years. In San Diego County they have not yet gained a foothold in any of the orange groves, but they have been introduced into the fair grounds, in the city of San Diego, where they overrun many of the ornamental plants both out of doors and in the conservatories.

FEEDING HABITS OF THE ANT.

The damage to orange trees by the Argentine ant must be either direct, through habits of feeding upon plant parts and tunneling and nesting about the roots, or indirect, through its relations with harmful insects and as a carrier of citrus diseases, or both. Not only were the nature and amount of the injury inflicted by the ant learned through a study of its foraging and nesting habits, but a successful method of controlling it as well.

It is not the intention here to specify all the foods which the ant has been observed to utilize, or to describe its well-known ravages into household supplies, but rather to describe its feeding habits in the orange groves and particularly in their bearing upon the orange trees. The ant is omnivorous, and though much of its food is derived from plant sources, it exhibits a distinct need for animal food and utilizes not only the flesh but also the excreta and other effluvia of animals as well. Its need for flesh food is so marked that in the artificial formicary, when flesh food is not furnished, it almost always will feed to some extent upon its own young.

FOODS OF THE ANT DERIVED FROM PLANT SOURCES.

Method of the Ant in Obtaining Plant Nectar.

The floral, and occasionally extra-floral, nectar of many kinds of plants forms the most dependable food of the ants from a direct plant source. The flowers of citrus and many other cultivated and wild plants are visited habitually for their nectar, which is lapped up from the area around the base of the stamens and petals, this area being evidently the location of the principal nectar-producing glands, at least in citrus.

With the aid of a hand lens the tube-shaped tongue of the feeding ant may be seen moving rapidly and continuously, in conjunction with the labial palpi, over the surface of the floral organs, while the food apparently is being pushed back by a thin, elbowed member that moves constantly within the tube. The ant often continues lapping up the liquid until a full crop is indicated by the distended semi-transparent gaster, this requiring from 15 to 30 minutes. It then usually rests for a period in the flower, or it may at once start its descent toward the nest. On their way down the tree forage-laden ants frequently rest in any sheltered location serving to exclude light and breezes, and almost invariably a group of ants resting motionless may be discovered in such places along the trails.

Ants Poisoned by Floral Nectar.

Occasionally the ants are poisoned by the nectar from loquat blossoms. On one occasion attention was attracted to a certain group of blossoms by the fact that most of the ants in that neighborhood were assisting sick comrades, carrying dead ants, or standing sluggishly about. Close observation of many of the last mentioned showed them to have the mandibles wide open—rather an unusual attitude. Under a hand lens one was seen finally to open the mouth so wide that the mandibles extended at right angles to the sides of the head and to regurgitate a drop of yellowish fluid. Obviously it was a sick ant. It did not attempt again to feed. The loquat blossom has a heavy, sweet odor peculiarly its own, but suggesting that of the peach or almond, and it seems probable that at times the nectar may contain traces of prussic acid. In addition to obtaining the nectar from the flowers, the ant gets a good proportion of its flesh food there, as will be shown later.

Utilization of Plant Sap and Fruit Juices as Food.

The ant also utilizes the unmodified plant sap from orange and some other trees whenever it is able to obtain it. It habitually feeds upon the sap from wounds in the bark and often has been observed working in considerable numbers on every freshly made cut of the

pruning saw in the orange groves, lapping up the sap, just as it does the nectar from flowers, and the sap-laden ants passing from the wounds to the nest in the soil. This habit of visiting cuts and bruises on orange trees may be of importance in the carriage of certain disease germs to places where they may infect the trees readily through wounds.

The ant is very fond of the juice of many kinds of fresh fruits and makes the most of the rotting oranges on the ground and the split fruit on the tree. It may be laid down as a practically infallible rule that the ants do not make the initial break into the rind or peel of fruits. This fact was announced long ago as true of European ants in general by Forel,[1] who, as a result of his observations of these ants on pear, apple, peach, and orange trees, concluded that they never make the first incision through the skin of these fruits. The same is true of the Argentine ant as regards the orange, fig, plum, peach, and loquat in Louisiana. In some orange groves in winter the juice from bruised, decaying, and split oranges forms the ants' principal source of food. The ants also feed to a large extent upon figs when the fruits become soft upon the trees and many fall to the ground. Entrance to even this soft, thin-skinned fruit is gained almost invariably through wounds made by birds and the adult wood-boring beetle *Ptychodes trilineatus* Fab., or through a minute break in the calyx cup or the wrinklelike cracks which commonly form in the skin of the Louisiana fig. As a rule the ants do not carry away particles of the flesh of fruits. The flesh gradually disappears from an attacked fruit because deprived of the juice which constituted most of its mass. On entering a fruit the ants first lick up all the juice ready at hand. A shred of the flesh then is taken in the mandibles and the juice squeezed out and simultaneously lapped up by the tongue. This is repeated until all the flesh of that particular fruit has disappeared.

Direct Injury to Blossoms and Other Plant Parts.

INJURY TO BLOSSOMS.

The ant sometimes chews into the stamens and petals of the orange and other flowers, but by no means habitually, and it is rare indeed that so many blossoms are injured as to cause any loss of importance. After examining thousands of blossoms in the worst ant-infested orchards during three seasons for such injury, it has been necessary to conclude that this activity of the ant is of no economic consequence. In certain situations where the ants are very numerous and desirable food relatively scarce some damage may occur in this way. It occurs

[1] Forel, Dr. Auguste. Les Fourmis de la Suisse, p. 422. 1875.

almost exclusively on isolated trees, where the number of blossoms and of host insects of the ant are low in comparison with the number of visiting ants.

The following points have been noted as being generally true where the ants do use the mandibles on the blossoms: The parts attacked are usually the petals and stamens of open and presumably pollenized blossoms, and in most cases there is no evidence that the fruit is injured thereby. The attack usually begins in a wound made by other insects, and the work of destruction proceeds slowly. As many ants as could be accommodated by the blossoms have been observed to work steadily for one-half day without being able to destroy two petals completely. The ants never have been detected carrying away particles of the blossom tissue; evidently they desire only the juice. The mandibles are used to squeeze the juice out of a portion of the petal or stamen, that it may be lapped up by the tongue. The work of other insects often may be mistaken for that of the Argentine ant in the orange groves of southern Louisiana. Thus the blossoms of both the orange and the loquat may be found badly chewed and ragged, with tunnels cut into the unopened buds, while all are covered with ants inside and out, seeming to make a positive case against the ant. When such cases have been examined with a determination either to see the ants cutting the holes or to discover what did cut them, the real culprit always turned out to be a bud moth,[1] *Uranotes melinus* Hübn., an unidentified case-bearing lepidopterous insect, or katydids.

A few of the flowers other than citrus more commonly visited by the ants in the Louisiana orange groves are those of the loquat or so-called Japanese plum (*Eriobotrya japonica* Lindl.), peach, cowpeas, clovers, dock, goldenrod, and aster.

INJURY TO ROOTS.

The possibility of the ant causing direct injury to plant parts other than the blossoms and fruit, and particularly to the roots, was investigated. In the orange groves the ants habitually nest in the ground near the base of the trees, and often the entrance to the nest will be found directly against the trunk. Many nests in these situations were examined, and both the underground tunnels of the ants and some of the roots of the trees traced for a considerable distance. Dead and dying trees which were said to have been injured or killed by the ants and healthy but heavily infested trees were selected for these examinations.

The principal facts brought to light were as follows: The ants never were found nesting directly in the root clusters of young

[1] Identified by Dr. Harrison G. Dyar.

orange trees. They never were found to have tunneled along the principal roots of the older trees, nor were nests found near enough to these roots to affect them. The smaller roots of sickly and dying trees were generally deficient in number. The most evident cause of the poor condition of these trees was gummosis, the trees in some cases being almost completely girdled by it at the crown, and the bark in this section and for some distance along the principal roots being in a rotten condition. No orange roots were found harboring insects of any kind; there were no host insects of the ant there. In a word, the roots had not the slightest injury traceable to the ants.

FOODS OF THE ANT DERIVED FROM ANIMAL SOURCES.

Animal Food Other Than Insects.

A considerable proportion of the food of the ant in the orange groves, even aside from the excretions of scales, aphids, and treehoppers, is of animal origin. The ant habitually feeds upon the flesh of all animals, from the round worms to the vertebrates, that become available to it. In addition to the dead and injured insects, which it finds in all sorts of locations, there is a more or less regular supply of the very prevalent crustacean known as the fiddler crab, which constantly is being crushed underfoot, and of certain small fishes occasionally left in the drainage ditches by the sudden removal of water by pumping. The ant also commonly visits piles of discarded oyster shells and feeds upon the particles of flesh adhering at the point of attachment of the oyster. Occasionally it also finds dead birds, field mice, rats, etc. It is unable to break the skin of a rat, as was proved by an experiment, but will clean out the liquids about the eyes and inside the mouth. The ant does not appear to eat muscular tissue in solid form, but shreds it off with the mandibles, lapping up the juices as it works, in the same manner as with fruits. In the artificial formicaries the particles of muscle not eaten are piled up in one of the chambers, and it seems possible that these may be drawn upon at times when meat is scarce.

In the stable the ant constantly visits the manure and captures the larvæ of house flies and other insects. It also visits human excrement, whether directly feeding upon it or solely for the capture of scatophagous insects is uncertain. Large trails have been found of ants carrying dung from chicken coops to the nest, and it appears that the ant may utilize this dry excrement for food. Often it is seen visiting bird's nests for the same purpose, though it also finds among the feathers certain refuse that is attractive to it and, perhaps, captures bird lice to some extent. It also has been seen feeding upon the liquid portion of freshly voided chicken excrement.

It is especially fond of sputum and the mucous secretion from the bronchial and nasal passages, particularly if voided by persons afflicted with a cold. The habit of the ant in getting into the mouth, ears, and nose of infants, whenever opportunity offers, is probably due to its fondness for mucus. Activities such as these, which are habitual with the ants to the full extent that opportunity offers, under certain circumstances obviously may be very important in relation to sanitation.

Living Insects as Ant Food.

The flesh food most esteemed by the ants seems to be made up of the insects which they capture alive. It is not solely for nectar that they visit the flowers of citrus and other plants, but also for the thrips, gnats, and other insects which they are able to capture there. A certain proportion of the ants foraging in the trees almost invariably are found to be carrying insects. The number so engaged will depend upon the availability of these insects. In a large number of observations on this habit, in all seasons, it was found that from as low as 0.49 per cent to as high as 45.8 per cent of the ants foraging in orange trees carried insects. Usually, however, less than 1 per cent will be engaged in capturing insects, and when the proportion is larger than 5 per cent it is because a special opportunity is offered. For example, on fig trees in Louisiana there is usually a period of emergence of psocids in the spring when other ant food is scarce, and the ants hang around the psocid groups and capture the insects as they emerge. Again, during the blossoming period of the small-leaved privet the ants are able to capture numerous thrips from the blossoms. The blossoms are narrowly campanulate, and the ants, unable to pass between the stamens, await and capture the thrips as they attempt to leave. Large numbers of foraging ants are found carrying white flies at each emergence period of the flies, on both orange trees and privets. All these insects, of course, may be captured from the same trees at the same time. For example, on one occasion, when all the ants carrying insects on a privet tree in one and one-third hours' time were captured and their prey examined, it was found that 32.7 per cent of the prey were thrips (*Frankliniella* sp.), 46.5 per cent nectar-feeding gnats, 13.8 per cent white flies, and 5 per cent psocids. Often, however, they are engaged almost exclusively in the capture of one particular species.

Large numbers of insects are captured on the ground, on weeds and ornamental trees, and in manure piles in the orange orchards of which no special account is taken because their capture has no bearing on the relation of the ants to orange trees. The ants also capture living and dead mealybugs, immature soft brown and black scales,

aphids, immature stages of the white fly, and adult aphid and scale parasites, but so rarely that this activity is unimportant. The more important relationship of the ant as an enemy of the white fly in the adult stage is discussed on pages 38–40.

INSECT EXCRETIONS OR HONEYDEW AS ANT FOOD.

The most dependable, if not the most abundant, supply of food of animal origin utilized by the ants in the orange groves is the honeydew excreted by the several species of soft scales, plant-lice, and treehoppers which it attends.

METHOD OF OBTAINING HONEYDEW FROM THE SOFT SCALES, APHIDS, AND TREEHOPPERS.

The ants can be best observed obtaining sweet excretions from their host insects on the warmer days of winter, as fewer ants are running at such times and they can be observed more closely without disturbing them. The process is essentially the same with one species of host as with another. Taking the black scale, for example, the ant approaches a mature or immature but settled insect and strokes the body with one antenna after the other, rapidly and rhythmically. If no liquid appears after 15 or 20 strokes, the ant usually passes on to another scale or rests motionless by the first. Unless the scales are very numerous a proportion of the ants always are waiting, and the principal function of the small shelter structures found over scale groups is believed to be to protect the waiting ants from light, breezes, and, sometimes, the too copiously falling honeydew and its attendant mold. When the scale is ready to excrete the anal plates open slowly outward and from between them is extruded a tubular organ, at the extremity of which appears a droplet of colorless fluid. This the ant takes and swallows at once. The tube is then retracted and the anal plates close. The whole operation requires only a few seconds, not allowing time for closer examination of the mechanism.

The extreme lightness of the antennal stroke suggests the possibility of the presence of minute sense hairs on the body of the scale, which, if they occur, probably are distributed over the entire surface, as the stroking is not confined to the immediate region of the excretory pore. Attempts to induce excretion by stroking with a hair in imitation of the ants failed. From scales under the microscope there was no response to palpation with hairs of various stiffness. When the shell was pierced with a needle the anal plates half opened reflexly, but not far enough for further observation.

The process is very similar with the mealybug, as the following observation will illustrate: The droplet of mealybug excretion is considerably larger in proportion to the size of the individual insect than that of either the black or the soft brown scale. Two ants were

watched as they simultaneously stroked a mature mealybug on fig. Soon the posterior pair of spines moved slowly apart and a fleshy, pyramidal organ was extruded, at the tip of which there slowly appeared a droplet of colorless excretion. This both ants grasped with their mandibles, one standing at each side, and held until it slowly disappeared down their throats. The excretion was distinctly viscous, as shown by the plainly visible indentations made in the globule by the two pairs of mandibles, and the slowness with which it was swallowed. Ants often have been captured carrying down the tree semisolid globules of mealybug excretion. These they carried in their jaws, as they would carry insects. The excretion of the fluted scale also is voluminous and viscid.

The ants also have been seen to obtain honeydew from a species of treehopper (family Membracidae) occurring on goldenrod in the Louisiana orange orchards. Only the larvæ of this insect (identified by the late Mr. Otto Heidemann as *Entylia bactriana* Germ.) were attended by the ants so far as observed. When ready to excrete, the tip of the abdomen was elevated and a droplet of translucent yellow liquid appeared. This was taken by the ants and carried in the jaws like a minute ball of jelly.

The ants will take the body juices of scales and aphids as readily as their excretions, and the aphids often have been cut with a needle for the purpose of observing this fact.

The ants induce excretion in aphids by stroking with the antennæ, in much the same manner as they do the scale insects. The consistency of the excretion of aphids varies considerably, that from some kinds being thick and jellylike, while from others it is almost watery. An aphid occurring on cypress in Louisiana, for example, excretes a very thick honeydew which the ants swallow slowly and with apparent difficulty. The ants often are seen carrying these semisolid globules of honeydew in their jaws to the nest. Usually the ant hastily seizes the droplet the instant it appears, the liquid being flipped off to a distance if not promptly taken. The black scale also appears to throw the excretion to a distance, though not observed, as much of the sooty mold collects on the upper surface of the leaves which are under the scales. Some of the aphids attended—for example, the common orange-infesting species—have well-developed abdominal protective siphons, but these organs are absent from others.

RELATIONS WITH INSECTS INJURIOUS TO CITRUS TREES.

It has been shown that the Argentine ant is rarely directly injurious to citrus, either through its feeding or its nesting habits. Through the one persistent habit of visiting freshly made wounds

on the trees it may be of great importance as a conveyor of citrus diseases, but the actual extent to which it increases the spread of diseases as yet remains to be determined. Since almost all the damage so far caused by the ant has been through its relations with the injurious citrus insects, this damage must be solely in the nature of an intensification of the work of these insects. Only that portion of such injury in excess of that normally caused by these insects can be due to their relations with the ants. It is, therefore, necessary to bear in mind that only a few of the citrus-infesting insects are of importance, and they cause practically all of the insect injury. The ant must be proved to enhance greatly the damage done by these major pests before a case can be made against it as a destroyer of orange trees. The major pests of citrus in Louisiana are four species of armored scale insects, the citrus white fly, and the rust mite, any one of which will cause more loss than all of the lesser pests, including the soft scales and the aphids, together.

RELATIONS WITH THE ARMORED SCALES.

Status of the Armored Scales of Citrus in Louisiana.

The four important armored scale insects of citrus in Louisiana are, in the order of their importance, the purple scale (*Lepidosaphes beckii* Newm.), the chaff scale (*Parlatoria pergandei* Comst.), the long scale (*Lepidosaphes gloverii* Pack.), and the white scale (*Chionaspis citri* Comst.). The purple scale is the most numerous and destructive of the citrus scales, infesting fruit, leaves, branches, and trunk, and generally incrusting the branches and trunk along with the chaff and long scales. The chaff scale infests nearly every budded bearing tree in the State, incrusting especially the trunk and larger branches, and at times overflowing onto the fruit and leaves in considerable numbers. The long and white scales also occur on most of the trees, but do not become so numerous as the first two, either of which would outrank them both as pests. The status of these scales does not seem to have changed much, excepting perhaps that of the white and chaff scales, in the last 12 or 15 years. The purple scale, according to Morgan,[1] was considered one of the most dangerous scales in the State at that time (1893). The white scale, however, considered by Morgan [2] as one of the most destructive of the scales, causing bursting of the bark, does not now get so numerous as the others and causes little damage. The chaff scale, which Morgan states was not recognized as very destructive,[3] now must be accorded second place to the purple scale as a scale pest of citrus in the State. Dr. Howard states that the chaff scale was the preponderating scale of citrus at a certain plantation on Bayou Têche as early as 1880.

[1] See Stubbs and Morgan, op. cit., p. 57. [2] Ibid., p. 64. [3] Ibid., p. 62.

It is worth noting here that the sweet seedling trees of Cameron Parish, which are apparently of Sicilian origin, are much more resistant to these scales than the budded trees. Although the more important scales occur on this type of tree, the infestation is always very light. The citrus white fly, likewise, has not become a pest on the Sicilian seedling trees, and these appear to be especially well adapted to the conditions found in southern Louisiana.

The status of other armored scales of citrus occurring in Louisiana is about as follows: The Florida red scale, which Morgan noted as occurring only at New Orleans and Southport,[1] just across the river, in 1893, is now found scatteringly throughout Orleans, St. Bernard, and Plaquemines Parishes on citrus, palm, banana, oleander, privets, camphor, and other trees. It never has been of more than very minor importance. The California red scale (*Chrysomphalus aurantii* Mask.), a very serious pest in parts of southern California, has been reported on an ornamental tree (*Podocarpus japonica*) in Audubon Park, New Orleans,[2] and has been observed there by the writer, but does not occur in the orange groves.

The Ant Does Not Attend the Armored Scales of Citrus.

The armored scales do not excrete honeydew or any similar liquid attractive to the ants, and are not, therefore, attended by the latter. On the contrary, they probably would become the prey of the ants if it were not for their protective shield or scale. Many hours of observations, extending over a period of nearly three years, on the actions of the ants toward the armored scales have shown conclusively that they do not directly attend the scales either in the expectation of receiving honeydew or of capturing emerging parasites, which, by the way, are neither numerous nor effective. In the course of these observations ants several times have appeared to be palpating armored scales with the antennæ, but on closer examination the real subject of their attentions always has proved to be a young mealybug or other soft scale resting close to the hard scales. The predominance of the armored scales makes impossible that their attendance should escape notice if it occurred.

It was discovered early that ant shelters sometimes occur over large and small groups of the diaspine scales, but this activity could not afford protection of the least consequence to these scales, for the number thus covered is infinitesimally small in comparison with those not covered. That even those scales under the shelters receive only dubious protection from them is shown by the fact that they are often infected with some of the prevailing scale fungi. The fre-

[1] See Stubbs and Morgan, op. cit., p. 60.

[2] Barber, T. C. The scale insects of Audubon Park. *In* Jour. Econ. Ent., v. 4, p. 450. 1911.

quent occurrence of living soft scales or of remains indicating that such had occupied these shelters is evidence that they generally were built while the ants were attending these scales and had no relation to the armored scales which they covered.

The forced conclusion is that any protection afforded the armored scales by the ants must be incidental and due merely to their presence on the trees and their very manifest habit of attempting to prey upon all insects not supplying honeydew with which they come in contact. For this protection to be so effective as to be of great economic importance the scales must have enemies so efficient as usually to keep them greatly reduced. The fact is, however, that these scales are not kept under reasonable control by their enemies, even in orchards where there are no ants.

Parasites and Predators of the Armored Scales of Citrus in Louisiana.

Although there was not time for a thorough study of the enemies of the armored scales of citrus in Louisiana, great batches of scale material from ant-free orchards have failed to produce more than a sprinkling of internal parasites. The more common hymenopterous parasites, reared from purple and chaff scale material selected because of the frequency of exit holes, were *Aspidiotiphagus citrinus* Craw. and *Coccophagus flavoscutellum* Ashm.[1] A small black lady-beetle,[2] *Hyperaspis signata* Oliv., with wing covers marked with a spot of red about the middle of each, feeds upon these scales to some extent, and a still smaller ladybeetle, *Scymnus puncticollis* Lec., is suspected of it. Larvæ, pupæ, and adults of a large coccinellid, *Chilocorus bivulnerus* Muls., frequently are found in large numbers upon trees overrun by ants, and a minute black species, *Microweisia misella* Lec.,[3] also often occurs on some of the trees by the hundreds. Both of these insects are suspected of feeding upon the early stages of the armored scales, but neither of them seems to be deterred greatly by the ants. At all events, they are found in considerable numbers on trees infested by the ants.

Influence of the Ant on Abundance of Armored Scales in Louisiana.

In addition to prolonged field observations on the relations of the ants to the armored scales, experiments were conducted for the same purpose by excluding the ants from certain trees and noting the effect of their presence or absence on the scales. Thus the ants were excluded from one of two vigorous young orange trees having an approximately equal infestation of the purple scale and allowed free access to the other. Notes were made at intervals on the number of

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[1] Identifications by Dr. L. O. Howard.
[2] Identified by Mr. E. A. Schwarz.
[3] Identified by Mr. H. S. Barber.

sound and parasitized scales, the presence or absence of scale enemies, and the activities of the ants. This experiment was started on April 28 and concluded October 24, 1914. There was a large colony of the ants about the base of the nonbanded tree throughout the experiment, but the ants did not visit the tree, except to keep it patrolled by scouts, until several soft brown scales became established there, and at no time were they discovered paying the slightest attention to the purple scales. No scale enemies of any consequence were seen on either tree, and there was never any evidence of parasitism. The results of this experiment are summarized in Table I.

TABLE I.—*Experiment to discover the effect of ants upon the armored scales of citrus. Louisiana, 1914.*

Date.	Ants present.			Ants excluded.	
	Number of sound scales present.	Number of scales showing parasitism.	Number and activities of ants on trees.	Number of sound scales present.	Number of scales showing parasitism.
May 7	97	0	Only 3 scouts in tree	283	0
June 3	125	0	None on tree	591	0
June 19	198	0	do	591	0
July 17	276	0	8 ants capturing white flies.	530	0
Aug. 13	1,130	0	A few scouts	1,372	0
Sept. 25	5,700 (estimated)	0	10 ants attending soft brown scale only.	7,200 (estimated)	0
Oct. 24	Trunk and main branches literally covered.	0	50 ants, all attending soft brown scale only.	Trunk and main branches literally covered.	0

Reference to Table I will show that on May 7 there were 97 scales on the ant-invaded tree and 283 on the tree from which ants were excluded. The number gradually increased on each tree from June to October, except that there was a slight and unaccountable decrease on the tree from which ants were excluded during June and July. On September 25 it was estimated that there were 5,700 scales on the ant-invaded and 7,200 on the ant-free tree. By October 24 the trunk and main branches of both were literally covered with the scales, and it was impossible to distinguish between the two as to infestation. The scales had increased at approximately the same rate on both trees. The health of the trees remained good throughout, except for a few yellow spots made on the leaves by the feeding of scale groups.

In another experiment the ants were excluded from a block of more than 200 bearing orange trees for several months, while an equal number of trees adjoining were left untreated as checks. The color of the trees in the treated block showed improvement over those in the check block, and this improvement was attributed to the

cultivation and pruning received by the trees. There was no apparent difference between the two sets of trees as to abundance of armored scales.

RELATIONS WITH THE SOFT SCALES.

STATUS OF THE SOFT SCALES OF CITRUS IN LOUISIANA.

Only four of the six principal citrus-infesting species of soft scales occurring in Louisiana have been discovered in the orange section of Plaquemines Parish. These are the soft brown scale (*Coccus hesperidum* L.), the citrus mealybug (*Pseudococcus citri* Risso), the Florida wax scale (*Ceroplastes floridensis* Comst.), and the barnacle scale (*C. cirripediformis* Comst.). No injury to citrus, serious or slight, ever has been attributed to the last two scales in the history of the orange industry in the United States, nor do they now cause noticeable injury to citrus in Louisiana. The first two are the only citrus soft scales occurring in sufficient numbers in the orange groves to attract attention.

Morgan[1] states that the citrus mealybug was very abundant in some of the orchards of Louisiana in 1893, especially in those well protected from winds and in thick-growing trees such as the mandarin, but was not a particularly serious pest at that time. These statements apply equally well for all practical purposes at present. The mealybugs occur scatteringly throughout the groves of Plaquemines, St. Bernard, and Orleans Parishes. They usually make a strong start in the spring and early summer and threaten seriously to infest certain orchards, but between the middle of June and the first of August they are brought under control by their natural enemies. Infestation goes the same course on fig trees in yards in New Orleans, except that the mealybugs are at times somewhat slower in being subdued there than in the orange groves.

Regarding the soft brown scale, Morgan's statement that "it appears and disappears, being kept in check by parasites, and for this reason has not attracted the attention of the orange growers"[2] also applies to-day. Its status is still essentially the same, though it is undoubtedly true that this scale will now be found in larger groups, in places, because of abundant attendance by the Argentine ant. It occurs upon nearly every budded orange tree over 3 years of age in the State, and also on banana, rose, and loquat in the orange groves. The important thing is, however, that it does not cause death or serious injury even to the twigs which it inhabits, does not blemish the fruit, and is not of noteworthy economic importance even in orchards overrun by ants.

[1] Op. cit., p. 69.

[2] Ibid., p. 68.

The black scale (*Saissetia oleae* Bern.) apparently was first noted in Louisiana in 1910, when it was taken upon certain plants in Audubon Park, New Orleans, by Barber.[1] It occurs commonly on oleander in many places about the city, but not a single specimen has been found in the orange groves.

The fluted scale (*Icerya purchasi* Mask.), according to Mr. Ed. Foster, who for many years has been an enthusiastic and discerning observer of insect life about New Orleans, occurred in places near present spots of infestation in and near that city as early as 1891, and this is confirmed by the statements of certain nurserymen and growers. It now occurs in many yards in the uptown districts of the city and in several nurseries, but has not been discovered in the orange groves.

The Ant as a Protector of Soft Scales.

INFLUENCE OF THE ANT ON ABUNDANCE OF MEALYBUGS ON CITRUS IN LOUISIANA.

It was not possible to find sufficiently heavy infestations of mealybugs in the orange orchards of Louisiana during the years 1913 to 1915 to make experiments to determine the relative increase on ant-infested as compared with ant-free trees. Even in orchards overrun with ants the mealybug infestations were scattering and did not persist long enough to permit the desired experiments and observations to be made. The nonimportance of the mealybug as a pest in the orange groves of the State, however, seemed to make it unnecessary to conduct special experiments on them. Nevertheless, mealybugs were fairly abundant on fig trees in the laboratory grounds in New Orleans, and experiments of this nature were conducted on these trees and also on vigorous young orange trees, which were especially colonized with mealybugs for this purpose. The ants first began to frequent the fig trees in large numbers early in April, at which time mealybugs were rare and could be found only in small numbers in the most hidden places, such as old wounds, under dead bark, etc.

On April 27 several groups of mealybugs which still occurred only in hidden places on the trunks and larger branches of the fig were transferred to each of two orange trees. By May 7 they had settled themselves permanently on the trees. Thereafter ants were excluded from one of the trees; in the case of the other, in addition to the ants patrolling it from the ground, a large colony, including 25 queens and many eggs and young, was transferred to the soil in the pot, where the ants took up their abode near the base of the tree. Observations were made at frequent intervals. The number of sound and parasitized mealybugs was counted and notes made on the

[1] Barber, T. C. The Coccidae of Audubon Park, New Orleans, La. *In* Jour. Econ. Ent. v. 3, p. 424. 1910.

known or suspected enemies, while the activities of the ants were observed on the unprotected tree. The results are summarized in Table II.

TABLE II.—*Influence of the Argentine ant on abundance of mealybugs on orange, Louisiana, 1914.*

Date.	Ants present.			Ants excluded.		
	Number of sound mealybugs on tree.	Number of parasitized mealybugs.	Number and kind of mealybug enemies on tree.	Number of sound mealybugs on tree.	Number of parasitized mealybugs on tree.	Number and kind of mealybug enemies on tree.
May 7	593	0	1 T	1,126	1	1 T.
May 13	234	110 (31.9 per cent).	2 T	859	209 (19.5 per cent).	4 T, 3 L.
May 21	214	3 (1.3 per cent).	4 D, 3 T, 1 L, 1 S, 1 C.	727	90 (11 per cent).	3 L, 1 C, 1 S.
June 3	20	0	0	7	0	2 D, 1 L.
June 12	3	0	1 P	0	0	0.
July 29	6	0	0	0	0	0.
Aug. 15	2	0	0	0	0	0.

Symbols: T=tubuliferan thrips; L=larva of the pyralid moth *Laetilia coccidivora* Comst.; D=larvæ of the dipteron *Leucopis griseola* Fallén.; C=coccinellids; S=Syrphus fly larvæ; P=the mealybug parasite *Paraleptomastix abnormis* Gir.

At the time of beginning the experiment, May 7, there were 593 mealybugs on the ant-invaded and 1,126 on the ant-free trees. The mealybugs gradually disappeared from both trees, as shown in Table II, until by June 12 there were practically none. There was considerable parasitization and the continuous presence in the mealybug groups of several different predacious enemies. On May 13, for example, 31.9 per cent of the mealybugs on the ant-invaded tree were found to be parasitized, and 19.5 per cent of those on the protected tree also were parasitized. On May 21 the percentage of parasitism among the ant-attended mealybugs was 1.3 per cent, whereas among those on the protected tree it was 11 per cent. Predatory enemies occurred among or near the mealybugs on both trees as long as the mealybugs lasted. The more common ones were predacious thrips, coccid-feeding larvæ of the moth *Laetilia coccidivora* Comst. (identified by Dr. Harrison G. Dyar), and the two-winged fly *Leucopis griseola* Fallén (identified by Mr. Frederick Knab), unidentified lady-beetles, and larvæ of syrphus flies. At least one parasite, *Paraleptomastix abnormis* Gir. (identified by Mr. A. A. Girault), was found on one of the leaves of the ant-infested tree. There was no evidence that the mealybugs were being attacked by fungus or other disease.

The slightly greater persistence of the mealybugs on the ant-frequented tree has little practical significance and in part was accounted for by the following circumstance: On June 12 a strip of

cloth was tied about the branch on which 3 mealybugs still remained on the ant-infested tree to mark their location, and the persistence of mealybugs in this tree after June 12 was due to their being sheltered by this cloth. The instinct for hunting shelter is much stronger in the young mealybugs than in any other of the soft scales and doubtless results from their being the preferred food of predatory insects.

During the course of the foregoing experiment on orange trees the mealybugs on the bearing fig trees, under constant attendance by the ants, had increased gradually, and during May overflowed their hiding place in the crevices of the bark and began to infest some of the smaller branches and leaves. On the branches they formed small groups and infested a considerable number of leaves, spreading along the underside, mostly in singles, twos, and threes. The period of maximum infestation of the fig trees extended from about the middle of May to the latter part of July. On June 26, while at its height, six of the trees were banded and the ants excluded for a period of 98 days, or until October 2, while six others were left unbanded and used as checks.

The work of the enemies and parasites had become evident by the middle of June, however, and it was apparent that the mealybugs were having a struggle to make further headway. By about the middle of July they had begun to lose ground, and from that time very rapidly disappeared from all unsheltered portions of all trees, banded and unbanded alike. The mealybugs very rarely, if ever, succeed in reaching maturity on fig leaves, even on ant-infested trees. A heavy parasitization was indicated early in July, due principally to a small, yellow-brown hymenopterous parasite.[1]

After August 15 the few mealybugs remaining on the large fig trees were in protected situations in the bark of the trunk and larger branches. The ant trails also had become thin in the unbanded trees by that time because of the scarcity of mealybugs. As for injury to figs by mealybugs, though a few small groups appeared on some of the fruits of ant-infested trees during this experiment, the percentage of fruits so affected was so small as to be negligible. Practically all the fruit was clean and bright at picking time. The

[1] This insect (*Paraleptomastix abnormis* Gir.) measures about 1 mm. long, some specimens less; general color yellow, marked on head, thorax, abdomen, and wings with smoky gray; the wings with three rows of dusky, broken, transverse stripes near base, middle, and tip, respectively, giving them a spotted appearance; legs and antennæ very long and slender, the former light yellow, the latter smoky brown. The insect has the peculiarity of keeping the wings elevated and in movement when running about on the leaves, which aids in distinguishing it in the field. The technical description by Girault is given in The Entomologist, v. 48, p. 184, London, 1915. While this parasite has been introduced into California, in localities in Alhambra, Duarte, and Sierra Madre, it has not yet become established as thoroughly there as in Louisiana, but if it does become so it will be an important factor in reducing the ant-attended mealybug infestations in that State.

leaves were of a clear, bright green, with very little sooting at any time. These trees, however, were receiving better attention than the average yard trees about the city. They had been kept well pruned and braced; weeds had been kept down, and the trees had shown vast improvement over their condition when first taken in charge. At no time during the three seasons in which they were under care was there any large amount of sooting of figs due to mealybugs. The fruit infestations usually were confined to one or two mealybugs in the calyx depression and the collection of a small group at this point on a small number of them.

The mealybug conditions for the years 1913 and 1915 were the same as described for 1914, both on fig trees and on orange trees in the city of New Orleans and in the orange groves proper of Louisiana. The sweet seedling trees of Cameron Parish are apparently not susceptible to the attacks of the citrus mealybugs at all; at least none ever was found on these trees.

Although certain groups of mealybugs may become larger because of heavy ant attendance in Louisiana, the status of this insect does not appear to have been changed by the protection received from the Argentine ant. The mealybugs usually appear in some trees in some of the orange groves as well as on fig trees during April. At times they become numerous enough to attract attention for a few weeks in May, June, and July, but in the last-named month they rapidly disappear, while their enemies increase, and by the last of July or early in August hardly any mealybugs can be found.

The most important enemy of the mealybug in Louisiana appears to be the Sicilian mealybug parasite (*Paraleptomastix abnormis* Gir.). Of the numerous predatory enemies, the most conspicuous were certain lady-beetles, larvæ of the green lacewing flies, larvæ of the small gray fly *Leucopis griseola* Fallén, and lepidopterus larvæ, of which the most prevalent was *Laetilia coccidivora* Comst. The last-named insect has the habit of spinning a more or less tubular web over the mealybug groups and feeding under its protection through the larva period, thus effectively defending itself against ants and other enemies. Another mealybug enemy of less importance, but sometimes fairly prevalent among mealybugs and other coccids, is a species of tubuliferan thrips which has not been identified.

INFLUENCE OF THE ANT ON ABUNDANCE OF MEALYBUGS ON CITRUS IN CALIFORNIA.

In parts of Los Angeles County, Cal., the attendance of the Argentine ant upon the citrus and other mealybugs has a much more pronounced effect in favoring persistent, heavy infestation than in Louisiana. This is especially the case with healthy trees that are

comparatively free from other infesting insects. Several experiments were conducted in that county in the summer of 1916 which bring out pretty well the varying effects of ant attendance on the mealybugs under different conditions.

Experiment I.

The subject of Experiment I was an orange tree whose 6 main branches had been cut back to stubs about 2 to 3 feet long. Three of the stubs, with 28 new shoots, were banded to exclude the ants, while the other 3, with 27 shoots, were left free to the ants. Mealybug infestation, prevalence of mealybug enemies, ant attendance, and vigor of tree were noted at intervals from the beginning of the experiment, April 14, to its conclusion, September 2, 1916. The results are summarized in Tables III and IV.

Table III.—*Effect of the Argentine ant on abundance of mealybugs on orange. Los Angeles County, Cal., 1916.*

Date.	Ants present.		Ants excluded.	
	Mealybug infestation.	Number of mealybug enemies seen.	Mealybug infestation.	Number of mealybug enemies seen.
Apr. 14	74 clusters and groups	28	73 clusters and groups	35
May 3	106 groups	89	83 groups	76
May 17	361 groups of 10 to 150 bugs each	19	45 groups of 10 to 30 bugs each	38
July 6	112 groups, 10 to 50 ovipositing females with egg masses	38	12 ovipositing females only with egg masses; 9 masses of destroyed mealybug material	15
July 17	As on July 6, but more young scattered over leaves	301	No living mealybugs	0

The larger groups or clusters of mealybugs at first occurred on the main branches, where they had passed the winter, but the migrating young formed smaller but populous groups at the bases of the smaller branches and of the leaves. It will be noted that at the outset of this experiment there was nearly complete uniformity in the amount of infestation between the branches from which ants were excluded and those to which ants had access. Substantial uniformity of infestation persisted up to May 3, when there was a somewhat greater number of groups of mealybugs and more scattered individuals on ant-invaded branches than on those kept free from ants. Between May 3 and July 17 the mealybugs rapidly diminished to complete disappearance on the branches from which ants were excluded, whereas on those to which ants had access mealybugs continued to increase rapidly for a time, reaching the high point of infestation on May 17. Thereafter the infestation decreased on these branches also, but much more slowly than on those

from which ants were excluded, remaining, on July 17, about one-third as heavy as on May 17.

Up to July 17, therefore, the presence of the ants had a very notable effect in increasing and maintaining mealybug infestation. On this date the band was removed from one of the branches so that reinfestation under ant attendance might be observed, and one of the branches previously free to ant attendance was banded. No marked results were obtained from this test. As indicated in Table IV, a slight reinfestation of mealybugs occurred on all the branches free from infestation on July 17, but there was a general decrease of infestation on both types of branches and on the entire tree throughout August. The only living mealybugs remaining on either set of branches during August were young which were scattered over the leaves, the insects being destroyed by their predatory enemies before reaching maturity, and by September 2 the entire infestation on the tree was reduced to an insignificant amount. In other words, on this particular tree the effect of the ant in increasing and maintaining the mealybug was marked up to the middle or end of July, but this effect was practically lost during August.

TABLE IV.—*Effect of the Argentine ant on abundance of mealybugs on orange. Los Angeles County, Cal., 1916.*

Date.	Ants present.								Ants excluded.							
	From Apr. 14 to Sept. 2.				From July 17 to Sept. 2.				From Apr. 14 to Sept. 2.				From July 17 to Sept. 2.			
	Number of leaves examined.	Number of living mealybugs.	Average number of mealybugs per leaf.	Number of mealybug enemies.	Number of leaves examined.	Number of living mealybugs.	Average number of mealybugs per leaf.	Number of mealybug enemies.	Number of leaves examined.	Number of living mealybugs.	Average number of mealybugs per leaf.	Number of mealybug enemies.	Number of leaves examined.	Number of living mealybugs.	Average number of mealybugs per leaf.	Number of mealybug enemies.
Aug. 7	50	1,000	20	9	189	21	0.111	0	405	81	0.2	0	150	30	0.2	1
Aug. 16	153	575	3.6	31	382	71	.18	1	251	122	.4	2	128	19	.14	17
Sept. 2	[1] 1,750	216	.12	0	[1] 1,465	50	.03	0	[1] 1,690	43	.02	0	[1] 645	49	.07	0

[1] All of the leaves examined.

The efficiency of natural enemies, as affected by the ant, was seen in the first period of the experiment, from April 14 to July 17. From April 14 to May 17 the number of mealybug enemies occurring on the branches from which ants were excluded did not differ widely from that on branches to which ants had access; yet, although by the latter date these enemies had reduced greatly the number of mealybugs on branches kept free from ants, their effect on mealybugs attended by ants was negligible. It appears that the mealybug predators are able to avoid capture by the ants, but are incapable of reaching the mealybug groups closely attended by them.

From May 17 to July 17 the mealybug enemies rapidly decreased and disappeared from branches kept free from ants and greatly increased on those where ants were present, following, as would naturally be anticipated, the available food supply. In the succeeding period of the experiment, from July 17 to September 2, after a certain amount of fluctuation, depending upon the supply of host insects, the natural enemies finally disappeared from all branches with the practical disappearance of their prey.

Experiment II.

The second experiment was conducted in the same locality, at Alhambra, Cal., on eight bearing navel-orange trees, four of which were banded with adhesives on April 24 and kept free from ants, while the alternating four were left accessible to ants for comparison. The results of this experiment, which are summarized in Table V, were similar to those in the preceding experiment, except that on the ant-invaded trees heavy mealybug infestation persisted throughout the experiment, or until September 12.

Table V.—*Effect of the Argentine ant on abundance of mealybugs on orange trees, Los Angeles County, Cal., 1916.*

Date.	Ants present.				Ants excluded.			
	Mealybug infestation.				Mealybug infestation.			
	On fruits.			On other parts of trees.	On fruits.			On other parts of trees.
	Total number examined.	Number infested.	Per cent infested.		Total number examined.	Number infested.	Per cent infested.	
May 24	800	[1] 200	25	Approximately as on Apr. 24.	800	[1] 150	18.7	Approximately as on Apr. 24.
July 10	1,405	328	24	242 groups of 1 to 5 mealybugs.	1,154	5	.43	12 groups of 1 to 5 mealybugs.
July 24	1,261	766	60.7	296 small groups, many scattered young.	1,263	34	2.6	7 small groups, many scattered young.
Aug. 7	1,596	923	57.8	206 small groups, many scattered young.	1,288	91	7.	Many scattered individuals.
Aug. 31	1,310	728	55.5	Many scattered.......	1,086	59	5.4	None.
Sept. 12	1,249	421	33.7	......do..............	1,282	64	4.9	Do.

[1] From 1 to 5 mealybugs hidden under the sepals only of each infested fruit.

At the beginning of this experiment, April 24, mealybug infestation was slight, only 103 scattered individual mealybugs and small groups occurring on the trees from which ants were excluded and 70 individuals and small groups on those to which ants were allowed access, the ant-excluded trees being slightly more infested.

On May 24 young mealybugs were found concealed under the sepals of 25 per cent of the young fruits on the ant-invaded trees

and 18.7 per cent of those on ant-excluded trees, showing a slight tendency toward worse infestation under ant attendance. The marked tendency of mealybugs to establish themselves under the sepals of the young fruits and in similar situations to secure sheltered feeding places must be taken into account when considering the subject of the transfer of mealybugs by ants to establish new colonies.

Between May 24 and July 24 mealybug infestation rapidly increased on the trees to which ants had access, while it decreased, with slight fluctuations, to an almost insignificant amount on those from which ants were barred. From July 24 to September 2 there was a slow reduction in the amount of mealybug infestation on the ant-traversed trees, an increasing number of mealybugs' remains indicating increased effectiveness of the natural enemies, which had become more numerous following the food supply. On the trees from which the ants were barred the mealybug infestation in the same period, with minor fluctuations in which the highest point was slight infestation of 7 per cent of the fruit, was maintained at a negligible amount.

The most important early activity of mealybug predators occurred on the very small fruits, these insects occurring with mealybugs under the sepals as soon as the mealybugs arrived there and preventing the growth of infestations from these spots. From July 24 to the close of the experiment, September 12, the number of predatory enemies, again following the available supply of food insects, was greater on the trees traversed by the ants than on those from which ants were barred, there being from five to eight times as many on the former as on the latter trees at the times examined. The principal enemies of the mealybugs occurring on these trees were Coccinellidae, Hemerobiidae, Chrysopidae, Pyralidae, and Syrphidae. During this latter period of the experiment, following the decrease in percentage of infested fruits on the ant-traversed trees, the increasing effectiveness of the mealybug enemies was manifested in the occurrence of an increasing number of fruits which had been rid of mealybugs, their previous infestation being indicated by bits of cottony secretion, sooty mold, etc.

Experiments III and IV.

Two other experiments conducted at Alhambra, Cal., with nursery trees and potted seedling orange trees brought out very similar results. The nursery trees, owing to too late transplanting, failed to thrive and did not become very heavily infested with mealybugs, but showed less plainly but quite as certainly the results of ant attendance in increasing these insects.

In the experiment on potted orange seedlings, 6 of the young plants were infested artificially with mealybugs, and on May 17,

after the mealybugs had become located, the ants were excluded from 3 of the plants on which there were 4,573 young bugs and allowed free access to the remaining 3, on which there were 3,094 mealybugs. On August 21 there were only 577 mealybugs left on the plants from which ants were excluded, 40.6 per cent of the leaves being infested with an average of 3.2 mealybugs each; whereas on the plants traversed by ants there were 5,461 mealybugs, 74.5 per cent of the leaves being infested with an average of 29 mealybugs each.

Experiment V.

In the fifth experiment, which was conducted at Duarte, Cal., it was demonstrated that the effect of the ants in increasing the abundance of mealybugs may be largely neutralized in the presence of unchecked infestation by the black scale (*Saissetia oleae* Bern.). Ten bearing naval-orange trees of about equal condition and equal mealybug, ant, and black-scale infestation, the last-named being heavy, and with fully 90 per cent of sooting of the leaves, the trees not having been fumigated since 1913, were selected for this experiment. On April 20 five of the trees were banded with adhesive mixture to exclude ants, and the alternating five left accessible to ants for comparison. The results of this experiment are summarized in Table VI.

Table VI.—*Effect of the Argentine ant on abundance of mealybugs on orange trees heavily infested with the black scale (Saissetia oleae). Los Angeles County, Cal., 1916.*

Date.	Ants present.				Ants excluded.			
	Mealybug infestation.				Mealybug infestation.			
	On fruits.			On other parts of trees.	On fruits.			On other parts of trees.
	Total number examined.	Number infested.	Per cent infested.		Total number examined.	Number infested.	Per cent infested.	
			Per ct.				Per ct.	
May 25	100	80	80	Many scattered mealybugs and small groups.	100	94	94	Many scattered mealybugs and small groups.
July 7	437	156	35.6	11.4 per cent of new shoots infested.	304	165	54.2	33.1 per cent of new shoots infested.
July 21	455	154	33.8	51 groups of 1 to 30 young and 17 adults with egg masses.	382	193	50.5	36 groups of 1 to 15 young and 47 adults with egg masses.
Aug. 15	409	143	34.9	81 groups of 1 to 5 mealybugs each.	376	165	43.8	20 groups of 1 to 5 mealybugs each
Sept 11	364	198	54.5	79 groups of 1 to 5 mealybugs each.	340	137	40.2	41 individual mealybugs only.

The initial mealybug infestation, on April 20, was much greater on these trees than on those used in experiment No. 2, there being on the trees left free to ants 1,661 individual mealybugs and small groups, and 10 infested ripe fruits; and on those from which ants were excluded, 1,896 individuals and small groups and 4 infested ripe fruits.

There was no appreciable increase of infestation between April 20 and May 25, but on the latter date a few mealybugs occurred under the sepals of many of the little fruits, a larger percentage of infestation occurring on the trees from which ants were excluded than on those to which they had access.

Between May 25 and July 7 the intensity of fruit infestation increased on all trees, though the percentage of fruits infested decreased. On July 7 about 18 per cent more fruits and 22 per cent more new shoots were infested on the trees protected against ants than on those frequented by them; and, while several fruits on the latter were infested more severely than any on the former, the trees free from ants continued to suffer a larger amount of fruit infestation from July 7 to August 15.

From August 15 to the close of the experiment, on September 11, the infestation was slightly worse on the trees to which ants had access. With the exception of such minor fluctuations as those indicated, however, the amount of mealybug infestation remained practically the same on ant-invaded trees as on those free from ants throughout the period from July 7 to September 11.

The struggle of the mealybugs to find suitable spots to feed and avoid their natural enemies on these scale-infested trees was marked. Every available spot free from sooty mold was occupied by them, and groups often occurred under sheets of the mold where it had lifted from the leaf. Even on the fruits the mealybugs were crowded by the black scale, and the practically equal and slight infestation on both sets of trees was due largely to this crowding.

Mealybug enemies were numerous on both sets of trees throughout the experiment, especially the green and the brown lacewings, and larvæ of the green frequently were seen feeding upon larvæ and cocoons of their own kind and of the brown lacewings. Bits of cottony secretion of the mealybugs entangling the exuviæ of mealybug enemies were numerous at every examination. Others of the more numerous mealybug predators were the lady-beetles *Hyperaspis lateralis* Muls. and *Rhizobius ventralis* Erh.,[1] the predacious caterpillar *Holcocera iceryaeella* Riley,[2] the predacious fly *Leucopis bella* Loew, and the predacious bug *Zelus renardii* Kolen.

[1] *R. ventralis* is primarily a black-scale enemy, but it also feeds upon mealybugs.
[2] Identified by Mr. Carl Heinrich.

Experiment VI.

In the following experiment, verifying the results of the one preceding, 4 trees longer subject to unchecked black-scale infestation were used, 2 of them being banded on June 2, the other 2 left free to ants.

Table VII.—*Effect of Argentine ant on abundance o fmealybugs in the presence of heavy black-scale infestation on orange. Los Angeles County, Cal., 1916.*

Date.	Ants present.			Ants excluded.		
	Fruit infestation.			Fruit infestation.		
	With mealy-bugs.	With black scale.	With sooty mold.	With mealy-bugs.	With black scale.	With sooty mold.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
June 2	37.5			32.5		
July 7	32.9	94.4	100	20.2	100	100
Aug. 15	48.1	53.5	100	20.5	45.7	100
Sept. 11	39.6	91.7	100	21.2	98.7	100

The fruit infestation on different dates, summarized in Table VII, shows that mealybugs were always somewhat more numerous on the fruit patrolled by ants, but that almost no change in degree of infestation occurred on either lot of trees. Most of the fruit on all trees was infested with young black scales, and all was sooty throughout the experiment.

RELATION OF THE ANT TO MEALYBUG OUTBREAKS IN SOUTHERN CALIFORNIA.

The foregoing experiments establish beyond a doubt that the attendance of ants upon mealybugs in Los Angeles County, Cal., has the effect of greatly increasing their abundance, particularly during the first half of the summer, upon healthy trees comparatively free from other scale insects, causing severe infestations where otherwise they would be so scarce as hardly to come to notice at all.

This does not mean, however, that the mealybug outbreaks do not occur in southern California except in the presence of ants. More than 300 outbreaks of the citrus and other species of mealybugs were reported during the summer of 1916 in and about Pasadena by Dr. A. G. Smith, the local county inspector. The writer inspected 167 of these for ants, but, while the Argentine ant was present in 72 of them, and other ants in 16 more, there were no ants in the remaining 79. Nevertheless, it is a fact that in Los Angeles County the enemies of the citrus mealybug bring it under control early in the season and generally cause its almost complete disappearance when there are no ants present to prevent.

Most of the mealybug outbreaks in Los Angeles County orange groves which came to attention during the summer of 1916 did not long remain very severe unless the Argentine ant was in attendance. An outbreak that occurred at Pomona may be cited as an example of what usually occurs under such circumstances. The mealybugs appeared in the orange trees in a certain locality and on walnut trees bordering the groves in April and May and were rather numerous on many trees during the latter month. By June 23, however, they had become so scarce that it was difficult to find them at all. None could be found on the walnut trees, and though some orange trees were found on which 15 out of 18 of the young oranges were infested, there were only from 1 to 10 mealybugs per fruit, hidden under the sepals. Predacious caterpillars, tubuliferan thrips, and small lady-beetles (*Scymnus* sp.) were also rather common under the sepals of these fruits and apparently feeding upon the mealybugs. The Argentine ant did not occur in this section, and there were no other ants in the worst infested trees at the time of this examination.

In San Diego County, on the contrary, the mealybug infestations were very bad in some of the groves where there were no ants in attendance at the time of the inspection, June 27 and 28. In the Lemongrove district three orchards were inspected, and all trees examined were infested very badly with mealybugs. In two of the orchards there were no ants of any species on the trees examined, but in the third a few small red ants occurred on some of the trees. The Argentine ant is not yet present in any of the orange groves of this county, although it has been introduced into the fairgrounds at San Diego. In the Sweetwater Valley the lemon trees inspected also were infested very badly with mealybugs, but while two species of ants were fairly common on some of the trees, the Argentine ant was not present. The infestations were equally as bad on a number of trees on which there were no ants as on those where the ants occurred.

In the Chula Vista district the infestation in the last two or three years had been quite as severe as at Lemongrove and in the Sweetwater Valley, but during the summer of 1916 it was so slight as to give no apprehension. This fact is attributed locally to the occurrence of mealybug enemies, and especially the lady-beetle *Cryptolaemus montrouzieri* Muls., in much greater numbers this year than usually.

In the El Cajon Valley, which is considerably farther inland than the three orange districts previously mentioned, and is almost completely shut in from air currents from the coast by the surrounding foothills, no mealybugs could be found, and Mr. H. M. Armitage, horticultural commissioner of San Diego County, stated that none had been found by the local inspectors.

In San Diego County, therefore, the conditions are such that the mealybug infestation is just as persistent in trees where there are no ants as in other localities overrun by them. This infestation may remain severe for from one to several seasons, and then there will come a period when the mealybugs will disappear almost wholly. This fact has just been illustrated in the Chula Vista district, and is no doubt due to variations in abundance of the mealybug enemies in that section.

INFLUENCE OF THE ANT ON ABUNDANCE OF OTHER MEALYBUGS IN CALIFORNIA.

The number and severity of outbreaks of other species of mealybugs in Pasadena have been increasing during the last three years. Dr. A. G. Smith, county horticultural inspector for the Pasadena District, states that in an inspection five years ago, covering the district bounded by Fairoaks, Colorado, and Lake Streets and the Altadena boundary line, only one mealybug infestation was found. An inspection three years ago of the same section of Pasadena produced 18 infestations, mostly on rice-paper plants. During the summer of 1916, up to the time this information was given, only the north half of this section, or from the Altadena line to North Orange Grove Avenue, had been inspected, but infestations were found in numerous places and on many more host plants than ever before. The worst of these outbreaks have occurred in territory invaded by the Argentine ant, and undoubtedly have been especially severe and persistent only where attended by this ant.

A number of the outbreaks discovered by Dr. Smith's inspectors early in the summer of 1916 had been greatly reduced, and the mealybugs had almost disappeared by August where there were no ants in attendance. The species concerned in these outbreaks and the host plants most commonly infested in this section are as follows: *Pseudococcus citrophilus* Claus. on pittosporum, bignonia, tecoma, citrus; *Pseudococcus bakeri* Essig. on Chamaerops and Washington palms, peppers, laurestinas, nightshade, tomato, banana, aralia, fig, camphor, and various garden plants; *Pseudococcus longispinus* Targ. on Dracaena palms, citrus, and some shrubs; *Pseudococcus ryani* Coq. on cypress hedge. Outbreaks of these species of variable degree occur every spring, but are less persistent and usually are controlled early by their natural enemies where no ants are present.

Another species, known as the golden mealybug (*Pseudococcus aurilanatus* Mask.), attacks the Araucaria tree in many localities about Pasadena and remains numerous throughout the summer, regardless of whether ants are present or not, and often causes the defoliation of the trees. This mealybug either is not controlled by

the various predators to the same extent as are the others mentioned above, or there may be some relation between it and its favorite food plant which makes this insect distasteful to these predators.[1]

INFLUENCE OF THE ANT ON ABUNDANCE OF THE FLUTED SCALE IN LOUISIANA.

The fluted or cottony cushion scale (*Icerya purchasi* Mask.) ranks second only to the mealybugs as to preference by the Argentine ant, owing, as with the mealybugs, to the large amount of viscid excretion given off by the insect. In spite of heavy attendance by the ant, however, the fluted scale has not been able to thrive and become abundant in Louisiana, except during the last season in New Orleans. This scale is believed by some, as previously stated, to have occurred on Metairie Ridge and in various places in New Orleans prior to the destructive freeze of 1895. Whether this is true or whether the insect has been imported into Louisiana only in very recent years is not certain. At all events the insect did not come to attention in the State until the fall of 1912, when it was found by the State inspector.[2] During the years 1913 to 1915, inclusive, closer attention was paid to the insect, and it was found at various places in New Orleans. Still it did not occur in the orange groves, and the infestations in and about the city were very scattering. Whenever they occurred in some numbers on a plant, they were viewed with such apprehension that extermination was attempted. It was, therefore, impossible to get a sufficient infestation under suitable conditions for experiments to determine the influence of the ant on their increase. During the summer of 1916, judging from reports received from New Orleans, the fluted scale spread more rapidly and became more numerous about the city than at any previous time, but the exact part played in this increase by the ant is not known.

INFLUENCE OF THE ANT ON THE FLUTED SCALE IN CALIFORNIA.

The status of the fluted scale in California in recent years is given by Quayle,[3] who states that the infestations become as bad at times in some localities as when at their height in earlier years. As a rule, however, the insect does not become numerous enough to be considered of economic importance.

No citrus orchards or trees could be found sufficiently infested with the fluted scale in southern California to serve for any adequate tests as to the influence of the Argentine ant. The scale occurred

[1] A condition such as this apparently occurs in the case of the fluted scale on Spanish broom in Ventura County, Cal.

[2] Tucker, E. S. Suppression of the Cottony Cushion Scale in Louisiana. La. Agr. Exp. Sta. Bul. 145. 1914

[3] Quayle, H. J. Citrus Fruit Insects. Cal. Agr. Exp. Sta. Bul. 214, p. 470. 1911.

very scatteringly and, as a rule, was parasitized or had been destroyed by its natural enemies. This was true in orchards overrun by ants and in orchards free from ants, indicating, at least, that so far in southern California the helpful influence of the ant, if any, in relation to this scale insect has not overcome the effective control of the scale by its natural enemies.

Aside from the well-known effectiveness of the Australian lady-beetle (*Novius cardinalis* Muls.), this control seems to be due, in Los Angeles County, chiefly to the parasitic fly *Cryptochaetum monophlebi* Skuse, aided, however, by hymenopterous parasites and the larvæ of lacewing flies.

INFLUENCE OF THE ANT ON ABUNDANCE OF THE BLACK SCALE IN LOUISIANA.

As already stated, the black scale (*Saissetia oleae* Bern.) does not yet occur in the orange groves proper of Louisiana, and, therefore, as with the fluted scale, no extensive tree-banding experiments could be conducted in this State during the seasons 1913 to 1915 to determine the effect of ant attendance on its abundance.

The black scale occurred in moderate numbers on oleander in New Orleans, and from these trees was transferred and colonized on young orange trees and an experiment of this nature attempted. The progeny of the colonized scales made an equally good start on both ant-free and ant-invaded orange trees. Nevertheless, the scales failed to reach maturity in a single instance, even where constantly attended by ants, and although they decreased a trifle more slowly where attended than where not attended by ants, all scales had disappeared from both banded and nonbanded trees within six weeks from the starting of the experiment.

INFLUENCE OF THE ANT ON ABUNDANCE OF THE BLACK SCALE IN CALIFORNIA.

The black scale has been rated as the most economically important of the citrus scales in California,[1] where it is generally controlled by fumigation. The observations on the relation of the ant to this scale were made in orchards in which fumigation had been temporarily neglected. In an experiment in which five scale-infested orange trees were banded to exclude ants in April, and a similar five left accessible to them, the amount of scale infestation remained practically equal on both sets of trees throughout the summer, from April to September.

In other words, after excluding the ants from five of these trees for a period of nearly five months but little difference in the amount of black-scale infestation or in quantity of sooty mold could be detected between them and five similar trees very heavily invaded by

[1] Quayle, H. J., op. cit., p. 445.

ants during the entire period. What difference existed was unfavorable to the view that the ants cause greater increase of the black scales. None of the trees had been fumigated since 1914.

In another experiment two more black-scale infested trees were banded against ants in June and two similar trees left accessible to them. These trees had not been fumigated for three years. As in the case of the first experiment, the amount of black-scale infestation remained practically equal on both banded and nonbanded trees throughout the remainder of the season.

Sometimes there is a greater amount of black-scale infestation on trees where there are no ants than on other trees of the same age and condition overrun by ants. Thus, in a block of orange trees not fumigated for two years more than half the fruit on a number of the trees on which there were no ants was scaly, while on a number of trees overrun by ants less than one-fourth of it was scaly. In this case the greatest scale infestation occurred on trees located next to older and heavily infested ones from which the scales had come by the usual means of dissemination, but there was no indication that the ants caused an increase of the scales on the trees on which they occurred.

In various orchards in Los Angeles and Ventura Counties, in which there were no ants and in which fumigation had been neglected for from two to four years, the black-scale infestation was quite as severe as is ever seen where the ants are present. In fact, in order to keep the black scale from reaching injurious numbers it has been found necessary every year to fumigate some orchards in which there were no Argentine ants and very few of other kinds. Sometimes a second fumigation is needed in the same season because of rapid reinfestation by what is called an offhatch, or an extra generation of scales, caused by their more rapid development on especially suitable trees.

It is evident, therefore, that the black scale in southern California is capable of reaching a very injurious degree of infestation in a single season, regardless of whether ants are present or not. Its natural enemies are not sufficiently numerous to prevent severe infestation, even though there is no interference from ants. The effect of the ant in accelerating the increase of this scale is therefore of little practical importance and does not compare with its importance as affecting the mealybugs.

INFLUENCE OF THE ANT ON ABUNDANCE OF THE SOFT BROWN SCALE IN LOUISIANA.

As was the case with the black scale, it was impossible to find a sufficient number of orange trees in Louisiana heavily infested with the soft brown scale (*Coccus hesperidum* L.) to conduct extensive

experiments to determine the effect of the ants. In a test conducted upon young orange trees colonized with the scales, two of the trees, on which there were 5,425 and 334 young scales, respectively, were banded to exclude ants, while a third, on which there were 3,100 scales, was left accessible to the ants for comparison. The number of scales gradually diminished on all the trees, accompanied by a corresponding increase of parasitized scale remains, until within two months from the time of starting the experiment practically all had been destroyed.

The destruction of these scales was caused almost exclusively by parasites, the percentage of parasitized scales increasing, with slight fluctuations, at the same rate on the tree frequented by ants as on the two trees from which ants were excluded. There was nothing in the condition of the trees or in their suitability as a food plant of this scale to prevent the scales from thriving, as was shown by the fact that a few sound scales which had secured perfect shelter from parasites remained on the trees as late as October, three and one-half months after all those not sheltered had been destroyed.

It was plainly seen in this experiment, and many other observations bear out this conclusion, that the internal parasites are the most effective enemies of the soft brown scale in Louisiana and that the Argentine ant does not extensively prevent the work of these insects. A considerable number of adult parasites were seen on these trees during the examinations, and fully as many on the ant-invaded trees as on the noninvaded ones. Two species of chalcids,[1] viz, *Eupelmus coccidis* Gir. and *Coccophagus coccidis* Gir., were reared from ant-attended soft brown scales in Louisiana.

While an orange tree occasionally would be found in Louisiana with one or more small branches very heavily infested with the soft brown scale, assiduously attended by the ants, the worst infestations that came to notice were on plants other than citrus. For example, in an orange grove at Buras, where this scale was present in small numbers and scattered on orange trees, one limb of a rosebush was found infested so severely that in a space 1 foot long on a branch about one-eighth inch in diameter there were 1,440 scales.

Large groups of this sort sometimes are found in which there is very little evidence of parasitism, but usually from 2 to 60 per cent or more of all the scales occurring in such groups either contain the parasites or show their exit holes.

The soft brown scale undoubtedly is held in check in Louisiana orange groves, regardless of whether ants are present or not, by its natural enemies and particularly by the internal parasites.

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[1] Identified by Mr. A. A. Girault.

INFLUENCE OF THE ANT ON ABUNDANCE OF THE SOFT BROWN SCALE IN CALIFORNIA.

There was no opportunity during the season of 1916 to study the effect of the ants on abundance of the soft brown scale in the orange groves of southern California because of the scarcity of the scales. Larger groups of this scale occur on various ornamentals where attended by the ants than where there are no ants, and its abundance on camphor, bottle, and pepper trees and many others along some of the streets of Pasadena where the Argentine ant occurs makes it appear that the ant has the effect of greatly increasing the infestations there. Neither the soft brown scale nor the closely related citricola scale[1] occurred in any greater number in the ant-invaded orange groves of Los Angeles County than in those where the ant did not occur. In Riverside County, on the contrary, large groups of the soft brown scale were found more easily in the ant-invaded than in the noninvaded orchards. Quayle[2] has noted that the soft brown scale becomes especially serious under the influence of the ant in that county. Several orchards were mentioned by Mr. D. D. Sharp, Riverside County horticultural commissioner, in which the soft brown scale had become so numerous as a result of attendance by the ant as to attract general attention. In one of the most severely ant-infested orchards, however, which it was said had not been fumigated for several years, there was a large parasitization of the soft brown scale, as high as 82 per cent of them being found destroyed by parasites in a group under heavy ant attendance.

It appears, therefore, that the Argentine ant may afford enough protection to the soft brown scale at times on certain trees or in certain localities to cause the formation of larger groups than is customary and retard the destruction of the insect by its natural enemies. This effect has not, however, been marked enough either in California or Louisiana to change the rank of the scale as a citrus pest of merely minor importance. This is due to the fact that internal parasites and not predacious enemies are the chief factor in the natural control of the scale.

RELATIONS WITH THE CITRUS WHITE FLY.[3]

THE ANT AS AN ENEMY OF THE WHITE FLY.

The only direct relation which the Argentine ant bears to the citrus white fly is that of predator. The first knowledge of this fact came as a result of observations made in an orange grove at Happy Jack, La., in April, 1913. At that time the prevailing belief, which

[1] *Coccus citricola* Campbell.

[2] Quayle, H. J. *In* Jour. Econ. Ent., v. 9, p. 472. 1916.

[3] The citrus white fly (*Dialeurodes citri* Ashm.). The cloudy-winged white fly (*Dialeurodes citrifolii* Morgan) also occurs in Louisiana, but is greatly outnumbered by the first-named species.

was shared by the writer, was that the ants fostered the white fly for its excretions, and when many ants were seen carrying adult white flies down an orange tree it was taken as evidence that they were transferring this pest to other trees and colonizing them thereon. As a principal occupation of the ants on nearly every tree was carrying white flies, however, and the reason for carrying only adults was not clear, the opportunity was taken to observe this work more closely.

It was noticed that comparatively few ants were carrying white flies up the trunk, but that a very large majority, certainly over 95 per cent, were carrying them down only. If the ants were establishing the white flies on other trees, it seemed that at least there should be somewhere near the same proportion carrying them up as were carrying them down the trees. Many of the ants therefore were traced as they carried the insects up and down the trees. Invariably those going up trees were traced to some cranny, where they poised in the dark for a rest or to avoid a breeze, or they would go up a short distance and then turn and go down again. Invariably those going down the tree were traced to the entrance to an underground nest, where they disappeared from view. Some of these entrances were directly at the base of the tree, but digging out such tunnels proved that the ants were not nesting about the roots of the trees or other plants on which the white fly might feed. It also disclosed the complete absence of underground colonies of living white flies and the presence of piles of dead remains of adults in the ant tunnels.

The next step was to examine white flies carried by the ants to determine whether they were living or dead. Some of them were living, and a good many more were dead, but the most important discovery was that a very large majority still had their wings crumpled, as they are immediately after emergence from the pupa case, showing that they were captured just as they emerged.

The percentage of white flies which the ants destroy must vary widely in the various groves at different times, and is probably never high enough to be of great economic importance. In a series of ten examinations to determine what proportion of the ants descending orange and privet trees with forage had captured white flies, the following data were gathered on the subject:

All the ants passing a point on the trunk going down the tree in a certain length of time, usually from 10 minutes to a half hour, were counted and classified as to whether or not they carried forage. Those carrying liquid forage could be distinguished by the distended gaster. The kinds of insects carried were noted without disturbing the ants where possible; otherwise the prey was collected. In

these examinations it was found that from as low as 0.7 per cent to as high as 54 per cent of the ants which had any kind of forage carried white flies. Other of the lower percentages were 0.9 per cent, 3.1 per cent, 3.2 per cent, and 13.8 per cent; while other higher percentages were 21 per cent, 21.7 per cent, 34.7 per cent, and 38.4 per cent. Most of these examinations were made at times when the foraging was not too heavy, so that the ants could be counted without danger of confusion, and the number of ants carrying white flies was often too large to count. The percentage of ants with forage in their possession in these examinations ranged from 16.1 per cent to 75.8 per cent.

The above phenomena, which were observed many times on citrus and other plants every season spent in Louisiana, always may be seen during the emergence periods of the white flies in orange groves invaded by the ant. At times the ants with their captives are so numerous that the most casual glance will discover them as they go wavering down the trunks with the white-fly wings spread above their heads like diminutive sails. At times, when such a caravan is suddenly struck by a light breeze, the little sails will scatter in every direction as the ants hunt for temporary shelter to prevent being blown out of their course. The only possible direct part played by the ant in its relations with the adult citrus white fly in Louisiana is that of predacious enemy.

Relations of the Ant with Immature Stages of the White Fly.

Investigation of the behavior of the ants toward larvæ and pupæ of the citrus white fly brought out the fact that, although they hover about these immature stages more or less, they do not palpate the larvæ or directly obtain their excretion, but that they watch over the pupæ solely for the purpose of capturing the emerging adult insects. Although the ants do not capture living white-fly larvæ, and only a comparatively few pupæ, they are occasionally seen carrying the latter. The pupæ taken are nearly always those in which the transformation to the adult is almost completed, the ants becoming impatient at waiting for the adult to appear or being impelled to attack by its attempts to extricate itself from the puparium. In some instances as many as 8.7 per cent of the white flies taken from the ants have been pupæ, but this proportion is doubtless above the average.

When most of the white flies on a heavily infested tree overrun with ants are in the larva stage the ants never are found in attendance in considerable numbers on the worst infested leaves. The ants have been seen to lick the leaf surface in the vicinity of white-fly larvæ and they undoubtedly secure a certain amount of white-fly

excretion in this secondary manner, especially when other food is scarce in the trees. If any large proportion of the white-fly excretion were taken by the ants, however, the sooty-mold fungus would be by so much the less prevalent in ant-invaded trees; this, however, is not the case. The ants do prevent to a very large extent the collection of excretory matter and the formation of sooty mold after mealybugs, even inducing such rapid excretion in certain young stages that the mealybug is unable to form the wooly covering, its body remaining almost naked and pink.

Effect of the Ant on Abundance of the White Fly.

An experiment to determine the effect of the ants on abundance of white flies was started on April 25, 1914, a young orange tree with 838 white-fly eggs being banded to exclude ants and a similar tree with 1,474 eggs kept accessible to ants for comparison. The percentages of young stages of the white fly dying from unknown causes and the quantity of new growth on the two trees were noted at every examination to make sure that the difference in white-fly infestation was not due to varying food conditions.

On May 13 there were on the tree from which ants were excluded 949 sound and 113 dead larvæ and pupæ and 189 unhatched eggs; on the tree that was accessible to ants there were 434 sound and 109 dead larvæ and pupæ and 112 living eggs. Between May 13 and June 12 the nonbanded tree was merely kept under surveillance by scouting ants, but on June 12 white-fly emergence was at its height and the ants had formed a heavy trail into the tree, where they were capturing the emerging adults. Living white-fly larvæ and pupæ were comparatively scarce and about equal in number on both trees. The remarkable thing was, however, that on the ant-invaded tree there were 167 empty pupa cases from which white flies had emerged and only 8 of the adult white flies, whereas on that from which ants were excluded there were 151 empty pupa cases and 130 of the emerged adults. In other words, the nonbanded tree was swarming with ants, some of which were carrying adults, and only 4.51 per cent of the emerged adults remained on the tree, whereas on the tree from which ants were excluded almost the same amount of emergence had occurred and 86 per cent of all the emerged white flies were still on the leaves.

From June 12 to about the middle of August the white flies increased faster on the tree from which the ants were excluded than on the other. On July 1 there were 5,435 living young on the former and only 1,919 on the latter. The percentage of dead was practically the same on both, being 12.9 per cent of all young on

the tree from which ants were excluded and 10.4 per cent on the tree to which they had access.

On July 17 the banded tree still led in white-fly infestation, there being 3,711 living young on this tree to 1,497 on the ant-patrolled tree, and by the 13th of August white-fly eggs, larvæ, and pupæ were too numerous on both plants to count. This final heavy infestation of both trees was expected, as it was improbable that complete white-fly control in the height of its breeding period could be accomplished by the ant.

The relations of the ants to emerging white flies brought out in the foregoing experiment led to similar observations on other trees On June 12, at the height of a white-fly emergence period, two more trees from which ants were excluded and two on which they were present were inspected. On the first two trees there were 431 empty pupa cases from which white flies had emerged, and 369 adult white flies, or 85.6 per cent of all which had emerged, still remained upon the trees. On the ant-invaded trees there were 600 empty pupa cases with emergence slits, but only 36 of the white flies, or 6 per cent of the emergence, remained upon the trees.

These observations indicate that the principal direct effect of the Argentine ant upon the citrus white fly in Louisiana is to destroy a varying proportion of them, thus entitling this ant to be called a white-fly enemy.

RELATIONS WITH APHIDS.

The relation of the Argentine ant to aphids has been observed principally on the orange-infesting species, chief of which is *Aphis gossypii* Glov. In Louisiana, however, certain observations have been made upon the relations of this ant with aphids on loquat, elder, privet, oak, cypress, and certain weeds.

THE ANT AS A PROTECTOR OF APHIDS.

The orange aphid appears in considerable numbers, sometimes very large numbers, on the newer growth early in the spring, often increases throughout April and May, causing some of the leaves to curl, and thereafter rapidly disappears, while a heavy parasitization is indicated by numerous dried skins punctured by the exit holes of the parasites. This condition, which has long existed both in California and in Louisiana, has not been altered materially even in groves and trees overrun by the Argentine ant. In Louisiana it occurs in scattered groups in January and February, often greatly increases in March, and becomes numerous on tender leaves and some of the blossoms in certain orchards during April and May. Even where heavily attended by the ant, however, its natural enemies,

and chiefly the internal parasites, have so reduced it by July or August that it is difficult to find specimens.

The following examples will serve to illustrate the ineffectiveness of the ant against the parasites of the orange aphis: On April 22, 1914, in an orange grove overrun with ants at Happy Jack, La., aphids were very numerous, averaging about 34 per leaf of the worst infested leaves, and undoubtedly would have done much damage had their increase continued long at the same rate. Even at this time, however, the aphid shells punctured by parasite exit holes indicated a parasitization of 29.7 per cent. Three hymenopterous parasites seen ovipositing in the aphids among the ants were watched until they had parasitized nearly every aphid on their respective leaves. While ovipositing in the aphids these little insects nimbly avoided the ants without flying. On May 15 living aphids could be found on these trees only with difficulty. In the meantime, too, many of the parasitized remains previously seen had been blown from the leaves, so that there was very little evidence that aphids had ever been numerous there.

On April 28, 1915, 15 per cent of the ant-attended aphids in an orange grove at Ollie, La., had been parasitized, but living aphids were still rather numerous, averaging 20 per leaf on those leaves examined. By May 12 the aphis infestation in this grove had decreased more than 50 per cent, and 49 per cent of the remaining aphids were parasitized. On May 27 an examination of twenty-five times as many suitable leaves as before revealed an average of only about two aphids per leaf, and 92.6 per cent of these were parasitized. The foregoing observations are merely examples of what may be seen annually in almost any grove in Louisiana in which ants and aphids occur.

At Alhambra, Cal., early in April, 1916, a trail of ants was found leading to flourishing small colonies of aphids on the new sprouts of an orange tree that had been cut back about 4 feet from the ground. The aphids were very numerous and not more than one per group showed evidence of parasitism. On April 21 fully half of the aphids had disappeared from this tree and 79.6 per cent of the remainder were parasitized. Ten aphid-feeding lady-beetles (*Hippodamia convergens* Gúerin) and a few syrphid-fly larvæ also occurred on the tree.

At Duarte, Cal., 20 young ant-invaded orange trees, badly infested with aphids on the new leaves about the middle of April, were almost completely free from them when examined on May 19. The few aphids remaining alive were being attended by the ants, but not one-tenth of 1 per cent of what had previously been present remained on the trees at this time, and discolored and dried shells with their parasite exit holes were everywhere present.

Again, at Sierra Madre, Cal., on June 16, scattered groups of aphids attended by ants on several trees revealed a parasitization of 92.1 per cent. On one of these trees 14 syrphid larvæ with 1 coccinellid larva and 15 or 20 ants were found working on the same groups of aphids.

The relations of the Argentine ant to an aphid commonly occuring on elder in Louisiana were observed especially because of the exceptional abundance attained by this plant-louse early in the summer and its abundant attendance by the ants. During March and April the aphids become too numerous for the trees to support and thousands fall to the ground, covering the grass under the trees and crawling back up the trunks in large numbers for days at a time. This aphid is progressively destroyed by predacious enemies and especially by parasites, until by the middle of June it invariably has been reduced to an insignificant number, which gather about the bases of the stems and leaves, where the best possible shelter occurs. On April 24, 1914, the comparatively few shells and aphids remaining on one of these trees were counted. There were only 1,667 in all, 529 of which were living, 68.4 per cent being parasitized. The principal parasite concerned was identified by Dr. L. O. Howard as a species of Aphidencyrtus.

On March 24, 1914, 9 robust young elder plants in pots were infested with the aphids and placed where the ants could get to them. About a month later, May 7, there were on all plants 2,436 living and apparently sound aphids and 985, or 28.7 per cent, parasitized. All parasitized shells were removed, and, on May 13, 1.18 per cent more aphids, parasitized since the previous examination, were removed, after which ants were excluded from 4 of the plants, on which were 418 sound aphids, and allowed access to the remaining 5, on which were 535 aphids.

On June 3 only 47 living aphids remained on the ant-free plants, but 119 were on the ant-invaded plants; and by June 16, at which time most all the aphids had disappeared from the large elder trees thereabouts, not a living aphid was left on any of the little plants.

In another experiment 2 robust elder plants were colonized with aphids on March 24. One plant was given 187 aphids and placed in a large trail of ants, and the other was given 185 aphids and placed where the ants could not get to it. By April 8 there were 3,194 living, apparently sound aphids on the ant-attended plant, an increase in 15 days of 1,708 per cent; and on the ant-excluded plant there were 2,514, an increase of 1,364 per cent. The more rapid rate of increase on the ant-attended plant seemingly was due to the activities of the ant, other factors being apparently the same in both cases. The number of living sound aphids soon began to decrease on both

plants, and as in the beginning it had increased more slowly on the ant-free plant, it now decreased more rapidly on that plant.

On April 25 the number of aphids on the ant-attended plant had decreased to 2,043, on the ant-free plant to 802, and, from that date on the decrease continued as follows: On the ant-attended plant there remained, on May 6, 182 aphids; on May 20, 18; on June 3, 23; while on the ant-free plant, on May 6, there were only 52 aphids, and on May 20 all had disappeared. The ants, therefore, appeared to give a slight advantage to the aphids up to this time, but by June 16 all had disappeared from both plants, the parasites having won in the struggle for their possession. It is seen therefore that although the ant attends the orange and certain other species of aphids having very efficient internal parasites, it is unable to prevent the destruction of these aphids and cause any noteworthy increase in their number.

TRANSPORTATION OF APHIDS AND COCCIDS.

Although at times nearly 50 per cent of the ants foraging in citrus and some other trees capture insects and carry them down the tree, taking it throughout the season the average is less than 1 per cent. About 8 per cent of the total foraging workers counted in all examinations were engaged in carrying all kinds of insects, but this is, of course, above the average, as counts were made only upon trees where the ants were engaged conspicuously in the transportation of insects. Only a fraction of 1 per cent, viz, 0.5 per cent, of the insects carried by the ants were scales and aphids, and only under exceptional circumstances is the number carried worth considering.

Extended observations on the activity of the ants in transporting scales and aphids have led to the following conclusions:

(1) The ants feed to a slight extent upon the surplus insects when its host scales or aphids are very numerous, upon those that have died from parasitism or some other cause, and upon male scales as fully as their ability to capture them allows.

(2) The ants utilize dead shells of the black and some of the armored scales for the construction of shelters and feed upon the softer by-products and detritus of these scales.

(3) Direct dissemination of orange scales and aphids by the ant is only incidental and is negligible. Indirectly the ants aid in the dissemination of some of these insects by greatly increasing them on particular trees, and from these points of heavy infestation they spread by the usual means.

Some of the facts which lead to the foregoing conclusions are as follows: A large majority of the scales and aphids carried by the

ants are dead. Thus about 94 per cent of the mealybugs taken from the ants were dead or discolored and scarcely able to move, while with the black scales and aphids carried the percentage of dead was still higher. On the other hand, of those insects which do not furnish honeydew to the ants most are alive when taken from their captors. Nearly all captive white flies are alive, as are the psocids, and even such fragile insects as thrips may be handled so lightly by their captors as to remain apparently uninjured. Thus, on one occasion, a thrips dropped by an ant at once started to run, when another ant seized and bit it viciously several times, after which the only sign of life was a twitching of legs and antennæ.

The ants almost always carry their scale and aphid hosts, as well as all other captured insects, to the nest, which is rarely if ever so situated as to afford living conditions to these insects. On rare occasions, in Louisiana, living mealybugs had been found in ant trap-nests, containing only dried straw and manure, but this happened in winter, when the mealybugs left not only the trees where there were ants, but also those in a part of the orchard where no ants occurred, and located on Bermuda grass. The soft scales found in ants' nests almost always have been dead. On one occasion when an exceptionally large number of ants carrying mealybugs down an orange tree could be traced to the nest in the rotting wood, many dead and discolored mealybugs and mealybug particles were found and 80 whole bugs counted. There were only 2 living mealybugs, and these appeared to be diseased, being unable to move except for twitching the legs a little.

The ants carry their host insects in considerable number only when these insects are exceptionally numerous, at which times they are able to supply a great deal more honeydew than the ants actually require. In Louisiana the ant attendance on the black scale and the citrus mealybug was nearly always in greater number than could obtain honeydew from them continuously. In California, however, the black scale, where unchecked by fumigation, becomes very numerous, overflowing the trees and covering them with sooty mold. On such trees the ants carry many scales at times. Thus in one orchard, in which both ants and black scales occurred in exceptionally large numbers, an unusually large number of ants were so engaged. Fortunately for observation, many of the nests to which ants could be traced were in the rotting stubs of cut branches. In these nests the scale phase most readily seen (that is, shells of mature scales) was scattered throughout the ants' galleries. Many nests, with their contents, were removed and examined, and the remains of numerous insects found there, but the black scales, of which there were 118 young stages, all dead, and 97 shells of mature scales, outnumbered

all others. Ants, with scales, also were traced to underground tunnels, which led neither to tree roots nor to any plant roots on which the scales could live.

Aphids, too, are transported only when the infestation is very heavy. The largest numbers carried were upon maple and elder trees, on which aphis infestation persisted somewhat longer than on orange trees because of more rapid parasitism of the orange-infesting species. A great majority of the aphids carried were dead. Since almost all are destroyed by parasites, some undoubtedly contain parasites when taken by the ants, but the number thus destroyed is too small to reduce the effectiveness of these enemies. The destination of the aphids carried was generally the underground nest. Only a very small percentage of the ants carry these insects up tree, and, when traced, these always have gone into one of the ant shelters for rest or, ultimately, retraced their steps down the tree.

Experiments have been tried several times to induce the ants to remove scales and aphids from unsuitable food to a place where they could thrive. As an example of these experiments, about two dozen elderberry stems, very heavily infested with aphids, were on one occasion placed in the midst of thousands of ants at the base of an elderberry tree and examined at intervals thereafter. At the end of an hour aphids were leaving the stems, many were scattered about in the short grass, and a considerable number of others were traveling up the tree trunk. A great majority of the ants paid no attention to these wanderers, but a few followed and stroked individual aphids while in motion. One such ant, becoming impatient after a few minutes of unrewarded effort, seized an aphid by a leg and pulled it about this way and that for a distance of fully a foot, when it let go and went its way.

Similar experiments were performed with mealybugs, infested stems being cut and placed among numerous ants in pots containing vigorous young orange trees. The ants would attend and stroke these mealybugs indefinitely, but in not a single instance did one transport a mealybug from a dying stem to the flourishing growth of the young orange tree. Many of the mealybugs would wander off the dry stems, and some of them would find their own way sooner or later into the healthy tree.

On one occasion, in California, a good opportunity was presented to the ants to assist mealybugs to regain trees from which they had been knocked by spraying with water under high pressure. The ant invasion was from "very heavy" to "extremely heavy" in about 70 per cent of the trees examined, the remainder having "light" or "very light" trails. Some of the mealybugs hit by the water were

knocked from one part of the tree to another, often landing on the trunk or larger branches. From 10 to 17 trees were examined each time, and in all these inspections only 8 ants were found carrying mealybugs, 7 of which were dead. In from one-half to 3 hours after spraying an average of 3 mealybugs per tree were crawling up the trunk; 18 hours after spraying the number had increased to 5 per tree average; at about 48 hours after spraying there was on an average only 1 mealybug returning to every 4 trees. Certainly the ants did not assist to any appreciable extent in their return.

The ants occasionally become impatient with aphids and scales that fail to excrete and seize these insects, just as at times they become impatient at waiting for an adult white fly to emerge and seize the pupa. The pile of mealybug remains found in the tree nest previously referred to indicates that the mealybugs were utilized as flesh food. There is little doubt that if sufficient time and pains were taken the ants actually might be observed eating occasional aphids and scale insects.

RELATIONS WITH INSECT ENEMIES OF SCALES AND APHIDS.

EXTENT OF CAPTURE OF PREDATORY AND PARASITIC INSECTS.

The ants are antagonistic to all the predacious and parasitic insect enemies of coccids and aphids, but not more so than they are to all other insects which do not furnish them with honeydew. The ants are habitually carnivorous and view all other insects, excepting perhaps some of the myrmecophiles, either as their cattle, furnishing them with liquid food, or as their prey, useful as flesh food. Although the ants take every opportunity to capture both predators and parasites of the scales and plant-lice, the number of this class of insects captured is very small. The close and constant attendance of the ants at scales and aphids, by preventing free oviposition and feeding of the natural enemies, accounts mainly for the ants' effectiveness as protectors of these pests, although the ants do feed to some extent upon eggs of certain scale predators.

A large number of insects have been taken from the ant and identified, and only 0.72 per cent of all the insects carried have been predatory on species attended by the ants. These consisted of larvæ of the Leucopidae, the brown lacewings, Syrphidae, and Lepidoptera, the last very rarely, indeed. It is seen, therefore, that the number of predatory enemies of the soft scales and aphids which the ant is able to capture is insignificant. The number of internal parasites captured is still smaller, being only one one-hundredth of 1 per cent of the insects taken from the ants.

MEANS OF DEFENSE OF THE LACEWING INSECTS.

The following observation will illustrate the methods of defense of certain of the predatory enemies of soft scales and aphids. The larvæ of the lacewing flies when attacked emit a fluid from the tip of the abdomen which, though so small in amount that it can scarcely be seen, strongly affects the ants. The larvæ will avoid the ants if possible by keeping out of their trails when moving, and when feeding upon mealybugs take up a position under the groups, where they are protected by their prey. On a tree in which many cocoons of *Chrysopa californica* Coq. occurred and which was overrun with ants a larva of the Chrysopa was seen crawling up the trunk on the opposite side from the ant trails. The larva was teased over into the midst of the ants, with the following result: An ant seized it by a foreleg, when it brought the tip of its abdomen forward and touched the ant, which then dropped to the ground. A second ant ran up, but as the chrysopid brought the tip of the abdomen forward, backed away, and the larva resumed its journey. Another ant took hold and, receiving the same treatment, backed hurriedly away in a circle, frantically brushing its head with the forefeet. Four ants then made a combined attack. The larva deliberately waited until they had a good hold, probably to be sure of its mark and conserve the secretion, when it touched them, and they acted precisely as had the preceding one. All these ants soon ceased to move and acted as if very sick. In the meantime the chrysopid passed out of the ant trail and proceeded up the tree. The larvæ of the brown lacewings defend themselves in precisely the same manner, emitting a minute globule of bright amber to red fluid that is evidently injurious to the ants.

MEANS OF DEFENSE OF THE LADY-BEETLES.

The larvæ of various coccinellids are protected by a covering of spines or of cottony excretion and by a thick yellowish material exuded from pores situated along the margins and dorsum of the body. Ants many times have been seen attempting to seize larvæ of the mealybug-feeding species *Hyperaspis lateralis* Muls., but not in a single instance did they succeed in capturing one. This larva, when feeding in the midst of mealybugs, usually remains perfectly motionless and does not attract the attention of the ants. When moving and attacked by them it flattens first one side to the surface, and, if attacked by several ants at once, it flattens down all around, leaving only the cottony filaments exposed. Sometimes the ants then will pull out masses of this cotton, and on one occasion they were

observed to pull out so much of it that the thorax of the lady-beetle was made completely bare. In spite of this the object of the attack was able to escape. At another time several ants were attacking one of these larvæ at once and each of them pulled out a mass of cotton from time to time. It soon was seen that some of them were unable to loosen the material from the jaws and were thus kept out of the contest.

The larvæ of such species as *Coccinella californica* Coq. and *Hippodamia convergens* Guér. rely principally upon immobility, flattening out, and their spiny covering for protection. The larva of *Rhizobius ventralis* Erichs. depends upon immobility, its natural flatness of body, and, in the presence of the black scale, which is its preferred food insect, the honeydew from the scales collects in the setæ on its body and becomes coated with sooty mold, blending to some extent with the sooty, sirupy leaf surface. The final emergency protection of all these larvæ, after having exhausted the defensive means of protection, is the so-called "reflex bleeding," or excretion, of a poisonous, repellent substance from the glands of the body. This occurs whenever the larva is roughly handled or there is danger of enemies actually destroying it.

The adult coccinellids defend themselves principally by flattening out, thus presenting the wing covers to the enemy, and by kicking. The kick consists of a sharp jerk of the leg by which the ant, threatening to seize it, is prevented from so doing. The ants often have been observed trying to capture adult lady-beetles, but never have they been seen to succeed. A single instance will illustrate the method of defense: On an orange tree overrun by the ants and also harboring numerous lady-beetles (*Coccinella californica*), one of the lady-beetles was seen traveling up the trunk in the trail of ants. Most of the ants were passing hurriedly by, swerving aside to avoid contact with it, but one ant was following and trying to seize one of its legs. This ant moved from side to side of the coccinellid, its jaws wide open, rushing it whenever there appeared to be an opportunity. Every time the ant would attempt to take hold, however, the lady-beetle would either give a quick snap of its leg or would lower the body on that side. This ant finally was joined by a second, and both tried for 10 or 15 minutes, without success, to capture the insect. There seems to be evidence that adult coccinellids also sometimes secrete a repellent fluid in very small amounts when attacked by ants, for the ants often back suddenly away on coming into contact with them. As a last resort adult coccinellids also have recourse to "bleeding," which seems capable of repelling many ants at once and even much larger enemies.

Lady-beetles often occur in large numbers on trees overrun by ants. This was commonly the case in Louisiana with a minute, shiny black lady-beetle, *Microweisia misella* Lec., which occurs in large numbers on trunk and branches of orange trees at certain times of the year. This insect apparently feeds upon eggs and young of the chaff and purple scales and is entirely oblivious of the ants. The same is true of the large twice-stabbed lady-beetle, *Chilocorus bivulnerus* Muls., which often occurs in large numbers in all stages upon heavily ant-invaded trees.

In California, large numbers of adult *Hippodamia convergens* and *Coccinella californica* and all stages of the black lady-beetle (*Rhizobius ventralis*) occur at times on orange trees overrun by ants. On one occasion more than 1,000 adults of the first two and the ashy gray lady-beetle (*Olla abdominalis* Say), all of which feed extensively on the excretions of the black scale, were counted upon 10 trees on which the ants were exceptionally numerous. Again, more than 60 of the black lady-beetles were found upon each of a number of young orange trees overrun by ants. A certain click-beetle, *Limonius subauratus* Lec.,[1] which feeds upon this excretion, is also fearless of the ants.

MEANS OF DEFENSE OF THE PREDACIOUS PYRALIDAE.

The principal means of defense of the larvæ of the predacious Lepidoptera which feed upon soft scales and mealybugs consists in moving the body rapidly from side to side like the cracking of a whip. The larva of *Laetilia coccidivora* Comst., however, protects itself chiefly by means of a tubular web which it spins over itself and its prey and through which ants can not pass. The nearly mature larvæ are protected rather effectively also by the spines on their bodies, and several times have been seen moving among numerous ants, apparently hunting for a place to pupate, without being molested.

MEANS OF DEFENSE OF THE SYRPHIDAE.

The larvæ of aphid and mealybug feeding syrphids also often are found on the leaves and fruit among the ants. The ants, though once or twice they have been found with very young larvæ of an unidentified species of syrphid in their possession, apparently never disturb them under ordinary conditions. The immobility and the spines of those species which have been observed working among aphids and mealybugs among ants appear to protect them adequately from the ants.

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[1] Identified by Mr. J. A. Hyslop.

INTERFERENCE OF ANTS WITH THE WORK OF PREDACIOUS INSECTS.

Although the ants are unable to capture in more than insignificant numbers the insects predatory on the soft scales of citrus, to a considerable extent they do interfere with their work of destroying scales, as has already been indicated. This is particularly true of those scales which occur in groups, such as the citrus mealybug and soft brown and some other scales, the predators being unable to oviposit in groups closely attended by the ants. Under normal conditions the citrus mealybug, in Los Angeles County, Cal., is held in almost complete control by its predacious enemies, chief of which are some three or four species of lady-beetles, the brown and green lacewings, and at least three kinds of predacious flies.[1] Rearings of enemies from a number of large batches of mealybug material collected among the ants at intervals from April to September, 1916, from scattered localities in Los Angeles County gave 71.8 per cent external feeders and 28.1 per cent parasites.

Against the internal parasites, however, the ants appear to be much less effective, as has already been indicated. Of the internal parasites reared from citrus mealybugs in California by the writer, only 9.7 per cent are known to be primary parasites of the mealybugs.

NESTS AND PROTECTIVE STRUCTURES OF THE ANT.

LOCATION AND PURPOSE OF THE NEST PROPER.

The Argentine ant, which is very ingenious at construction, builds its nest to meet the requirements of a comparatively few simple needs, a primary one of which is darkness. Aside from any special aversion which the ant may have to light, it seeks the darkness for safety, and it is only in the dark that the workers ever rest "off guard." The queens, especially the older ones, spend nearly all their time where the darkness is greatest, and when moving in the trails of the foragers, which they frequently do, invariably pass rapidly from shelter to shelter, spending as little time as possible in the open places. The ants never permit their young to remain in the light for long at a time, and both they and the great mass of the queens always are found in the darkest, most obscure parts of the nest.

Another requirement of the ant is a proper regulation of temperature and moisture to suit its young and itself. In exceptionally dry weather, such as often occurs in Louisiana from February to April or May, and in California throughout every summer, the nest will

[1] The natural enemies of the mealybugs of citrus in southern California are being studied by Mr. R. S. Woglum and are referred to here only in a general way, as necessary to show their relationships to the Argentine ant.

be tunneled into the ground. The depth will depend upon how far it is necessary to go to find the needed amount of moisture. It is in the underground nest also that the most comfortable temperature can be found, both in summer when it is very hot and in winter when it is very cold. In the cities the walls of buildings often are utilized, the ants taking advantage of the artificial warmth and shelter afforded. In rainy weather, when the soil is very damp, the underground nest will be abandoned for a location above ground, in buildings, trees, piles of dry weeds, piles of lumber, etc., and under almost any kind of shelter. When the ants are caught in the ground by a sudden rain, in situations where there are no convenient trees, buildings, or other shelter, "sheds" are constructed out of particles of soil and trash along the surface of the ground. These sheds are sometimes very large and are elaborately tunneled into galleries and pavilions. They dry out much more rapidly than the packed soil of the ground, and the young are kept in them until the ground again becomes dry.

OFFSHOOT NESTS AND RUNWAYS.

The ants habitually construct temporary quarters and utilize natural shelters along the foraging trail, especially if the food supply is distant from the nest, as places in which to rest, secluded from light, heat, and wind, and in which wandering queens may hide.

If the food supply is large, attracting many ants for a long period, the ants gradually construct runways, or series of shelters, between the nest and the food source, tunneling them in the ground or building them up of particles of soil and trash, according to circumstances. As these structures are built toward the sources of food and the queens are more or less constantly traveling in the trails of the foragers, it is in this direction that the colony expands. Whenever one of these wandering queens finds a suitably dark and secluded spot along the trail she makes her abode there permanently, deposits eggs, and starts a secondary colony. Queens, eggs, and young occur almost constantly in the larger, more secluded shelters along the foraging trails. This is the most important means of local spread of the colony.

A good illustration of the formation of offshoot nests in the ground occurred in the field poisoning tests at New Orleans. A supply of poisoned sirup kept near a fig tree for several months in 1913 attracted ants from three colonies in turn, all of which finally deserted the neighborhood. On October 2 workers from a fourth colony, nesting in an outbuilding 72 feet distant, arrived, and by October 8 the file of ants from nest to jar had increased enormously.

The ants soon began tunneling into the ground at short intervals along the entire course of the trail, and by October 15 these shafts were numerous. The foragers still followed the original trail along the surface of the ground, but could no longer be traced for its entire length, as they were continually disappearing into the tunnels. Queens gradually separated from the original colony and took up their abode in the tunnels, until finally there was a string of small colonies all along the trail from mother colony to sirup. The original purpose of the tunnels doubtless was to protect the workers from light and heat while they rested from their labors, but the queens found them well adapted for nesting purposes.

SHELTER STRUCTURES, OR "COW SHEDS."

In the trees the ants invariably utilize such natural shelters as cracks and depressions in the bark, abandoned tunnels of borers, the space between touching leaves and fruits, etc., often further excluding light by piling particles of trash along the edges of cracks and walling in the space between nearly touching leaves, fruits, and branches. A portion of the ants foraging in trees almost invariably may be seen retracing their steps up the tree, carrying either liquid forage or prey with them. If traced, these ants usually will be found seeking a rest in the nearest shelter of the sort mentioned. Sometimes, while resting, their forage is deposited nearby and occasionally thereafter forgotten; at other times it is held indefinitely in the jaws.

The erection of the so-called "cow sheds" over scale insects and aphids is a further extension of this habit of building shelters in which the worker ants can rest. The number of ants attending aphid and coccid groups is almost always greater than can secure honeydew continuously. Some of them, therefore, always must be waiting until their hosts have a fresh supply ready. During this period of waiting and unrequited solicitation the "cow sheds" serve the usual ant-protective purpose. These structures, of course, may protect from enemies the particular insects covered by them, but, even if this protection were absolute, no great number would benefit by it, because comparatively so few are covered. The occasional occurrence of parasitized remains of scales under these "cow sheds" indicates, furthermore, that the protection afforded even those comparatively few scales is often faulty.

On orange trees badly infested by the black scale shelter structures sometimes are found over groups of mealybugs, and in this case their most important function happens to be protection of the ants and mealybugs against the honeydew of the scale and its accompanying

sooty and green mold. Again, it seems to be primarily the ants that are protected, as they await the excretion from the mealybugs.

Perhaps the clearest proof that these shelters are built mainly in response to the needs of resting worker ants is the fact that under certain circumstances they will be built on the tables supporting artificial formicaries, where no scales or aphids occur. Six formicaries of the Janet type were kept on small tables set in pans of oil (see Pl. IV). Food, poisoned sirup, and water were placed on the tables outside the formicaries. When sick from a poison, the ants are very eager for water with which, perhaps, to wash out the crops, and numerous sick ants constantly hung about the water plate. Whenever sufficient trash was allowed them they would build a shelter tent from the edge of the formicary to that of the water dish, and this tent always would be full of ants regurgitating the poison and cleaning each other's mouth parts.

THE HABIT OF BURYING NOXIOUS SUBSTANCES.

Another activity of the ant somewhat along this line is the habit of piling débris upon noxious substances. On rare occasions they bridge bands of sticky material placed on the tree trunks in this manner. Generally, however, this is done only where the substance is actually injurious. In the field poison tests frequent cases were observed where the shelter-constructing and trash-piling habit merged into one. When foraging at the poison jars it was of common occurrence for the ants to construct out of particles of soft soil elaborate shelters about the sides of the jars, and sometimes completely over them. (Pl. I.) As they learned the effects of the sirup they often would deposit more and more particles on the sponge within the jar and finally fill the entrance hole completely. In one case, for example, they partly covered the sponge and filled the entrance to one of the jars nine times in the course of several months. In an experiment with moth balls placed in a saucer with sirup poured over them, the ants eagerly took the sirup for a week, at the end of which time there were large numbers of dead in the mixture. The ants then became engaged principally in removing the dead. The saucer had been placed on a piece of white crepe paper, and when this accidentally got wet the ants bit out particles of the paper and constructed an elaborate shelter completely around the edge of the saucer. Under this large numbers of workers might be found at all times. As they continued to feed and get poisoned, however, they began piling bits of paper on the moth balls and finally completely covered them with the "confetti."

CULTURAL CONDITIONS IN ANT-INVADED VS. ANT-FREE ORANGE GROVES IN LOUISIANA.[1]

As already stated, the Argentine ant infests only slightly more than 26 per cent of the orange groves of Louisiana as yet. It was found that 40.7 per cent of the groves that had never had the ants in them were in "poor" condition, while about the same proportion (43.9 per cent) of those that were infested with ants were in good condition. In other words, about 15.4 per cent more of the ant-invaded groves were in "poor" condition than of the noninvaded groves, but this is probably in large part due to the greater neglect of the ant-infested trees because of that infestation, many of the owners becoming discouraged as soon as they found the ants present. A considerable number of groves had been abandoned completely because the ants had gotten into them. A slightly greater reduction in crop had occurred in the groves infested by ants, this reduction being, however, only about 0.22 box per tree greater than in those free from ants. Both the maximum and the last (1914) crops were far below what they should be in both ant-invaded and ant-free orange groves for trees of their age, being in each case less than 1 packed box per tree. In Cameron Parish the large sweet seedling orange trees, in which the Argentine ant does not occur, helped to raise the production average for the groves free from ants, as these trees produce from 5 to 15 boxes each.

Thus it is seen that there is practically no difference between those groves in Louisiana where the ants are present and those where they are not, either in the condition of the trees or in the amount of fruit produced. It is undoubtedly true, however, that where the scale, white-fly, and rust-mite infestations are heavy and no attempt is made to control them the crop will be reduced considerably. The effect of these insects also will be unusually pronounced on trees that are weakened by too close planting, poor drainage, and cultural neglect. The ants appear to have no effect on the rust mite.

That groves completely overrun with the ants and in a badly run-down condition from neglect can be revived and brought back to their normal bearing condition without treating the ants or keeping them from the trees has been demonstrated. The principal features of this work will be related here briefly.

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[1] The data on conditions affecting the culture of orange trees in Louisiana were obtained partly by means of questions submitted to the orange growers, partly by personal inspection of the groves, and are complete on about 96 per cent of the groves of the State. Those groves with a large percentage of trees fairly large for their age, symmetrical, with moderately dense foliage, of good color, and bearing an average-sized crop according to local standards, were classed as "good." Those showing a large percentage of undersized trees, with thin foliage, many dead and dying branches, poor color, lack of growth, and poor crop were classed as "poor."

PROTECTIVE "SHEDS" OF THE ARGENTINE ANT.

Surface shelter of soil particles constructed by the Argentine ant about a poison jar. (Original.)

LOUISIANA BUDDED ORANGE TREE.

Peculiarity of growth of the *Citrus trifoliata* stock, and a comparatively very slight incrustation of lichens. (Original.)

DEMONSTRATION IN IMPROVEMENT OF ANT-INVADED GROVES IN LOUISIANA.

If preventing the Argentine ant from getting into the orange trees would effect the practical commercial control of the chief armored scales and the white fly in Louisiana, as it does that of the citrus mealybugs in Los Angeles County, Cal., the problem of controlling these insects would be simply one of getting rid of the ants. The natural enemies of the principal pests of Louisiana, however, are unable, even in the absence of ants, to prevent severe infestation. On the other hand, if thorough measures of control were practiced against these insects, there should be no reason to worry about the ants. If the citrus mealybugs in California orange groves were as thoroughly controlled by the regular fumigations as are the armored and black scales, the ants could do only a negligible amount of harm through these insects.

DESCRIPTION OF DEMONSTRATION ORCHARD.

The orchard reclamation work about to be described was conducted on a grove at Ollie, La., practically abandoned, except for the harvesting of the crop. The grove consisted of about 1,055 sweet, naval, mandarin, tangerine, and jaffa trees, a block of 603 of which were treated, the remaining 452 being left as checks. All the trees were very thinly foliaged, with small tops, and many of them with multiple trunks. Many of the leaves were yellow and a moderate number of branches were dead. The trees were poorly shaped, and branches were much tangled as a result of bad pruning. Many of the trees were suffering badly with gummosis,[1] some being almost completely girdled about the base of the trunk and larger roots by this disease. (See Pl. III.)

The ant infestation was as heavy as has ever been seen in any orchard. All the trees were very badly infested with chaff, purple, and long scales, the first named being exceptionally numerous. Almost all the fruit had been very badly discolored by the rust mite every year, and, in some years, infestations of the citrus white fly were also severe.

The largest crop ever produced by the full orchard of 1,055 trees was 1,400 boxes, occurring in the year 1911. The crop of the 1914 season had been only 400 boxes; or, in other words, the orchard had suffered a crop reduction of 71.4 per cent in three years.

TREATMENT OF THE ORCHARD.

The demonstration work of improving this grove was started in February, 1915, and continued until interrupted by the hurricane of

[1] Also called "sore shin" disease.

September 29, 1915. The treatment consisted solely of spraying, cultivation, and tree surgery.

Spraying was conducted against the chaff and purple scales, citrus white fly, and rust mite, and for the destruction of the lichens and moss which covered the trees (see Pl. II). The trees were sprayed only three times, the first application, for scales and the white fly, being started February 12; the second, for lichens and moss, May 12; and the third, almost exclusively for scales and rust mite on the fruit, on July 26. Two different brands of paraffin-base lubricating oil made into emulsions containing 1 per cent of the oil and 0.5 per cent of soap were used in the insecticidal work. A commercial lime-sulphur preparation was used in the fungicidal work.

The tree surgery consisted of pruning to improve the shape of the trees, the removal of wood diseased with gummosis, and the cutting back of Jaffa trees preparatory to rebudding. In some cases where the trees branched from the ground into several trunks, those trunks with poor tops which gave no promise of improvement were removed entire. The pruning of smaller branches was very light and consisted in the removal of all dead ones and thinning out of those entangled. All wood infected with gummosis was gouged out with a chisel and mallet and the wounds painted with a mixture of 1 part of creosote to 2 parts of coal tar. This work was all conducted in the spring, from March to June.

The demonstration plat was clean cultivated throughout the season by plowing and cross-plowing, followed by disking both ways of the orchard, four cultivations, March 8, May 12, June 21, and August 26, respectively, being necessary. Close to the trees, where the plow could not reach, the weeds were kept down by hoeing. As the orchard had never before been cross-plowed, a good many fairly large roots were broken in this work, but the trees did not suffer any apparent ill effect from this rough treatment. The drainage ditches surrounding the plat were all deepened about a foot and the weeds choking them removed.

RESULTS OF ORCHARD TREATMENT.

Within three weeks after the application of the lime-sulphur solution most of the lichens with which the trunks and larger branches were coated had fallen off completely, a solution of 30° Baumé, at 1 volume to 50 volumes of water, accomplishing this result.

Owing to the thinness of the trees and scarcity of food in proportion to the number of scales in this orchard, an exceptionally large number of these insects settled on the fruit. A count of the chaff and purple scales on 100 fruits from each of the two blocks on June 23 gave 112 on the sprayed fruits and 3,365 on the unsprayed, rep-

resenting a reduction of 96.7 per cent by spraying. By May 27 the leaves of the unsprayed trees had become quite badly infested with white flies. A count of those on 100 leaves picked at random from these trees gave 26,200 larvæ and pupæ, while on an equal number from the sprayed trees there were only 73, a reduction, therefore, of 99.7 per cent.

The rust mite began to appear on the fruit in June, and by the 23d of that month there were 50 to 60 mites per fruit on unsprayed trees, while on the sprayed they could only be found on the row of trees adjoining the unsprayed block and then only to the number of 10 per fruit.

On August 5, after the second insecticidal application, examination of 100 fruits on the sprayed trees gave 987 scales, or an average of about 9 per fruit, and 89 rust mites, the latter being so scarce that they were difficult to find. The unsprayed fruits were so badly infested that scales could be counted in the time available on only 10 fruits, on which there were 6,982, and the rust mites were quite too numerous to count. Fully 75 per cent of the unsprayed fruit had by that date become discolored by the rust mites.

By September the trees in the experimental block had responded beautifully to the treatment, and many persons commented on their improved appearance.

About ten times as much new growth occurred on these trees as on the untreated trees. The fruit was larger, and a very large percentage of it entirely clean. The storm of September 28–29, however, blew down and broke many of the trees and knocked approximately 87.2 per cent of the fruit to the ground, preventing bringing the work to a completely satisfactory conclusion.

It was possible, however, to count most of the fruit on the ground and that on the trees and examine it for insect injuries. There were practically twice as many fruits per producing tree left on the treated as on the untreated trees. Owing to the morass of weeds in the untreated block and to much of the fruit having been removed and sold by the owner, it was impracticable to count the fallen fruit in that block. In the treated block all the fruit which was not washed out of the orchard was counted and examined for insect injury. There were on the ground and on the trees 69,672 sweet oranges, tangerines, and mandarins, which, averaging about 200 to the box, made approximately 348 packed boxes of fruit. It was estimated that nearly one-fourth of the fruit was not recovered. The production was, therefore, about 435 boxes, or more than as much fruit as the entire orchard had produced the previous year, as a result of only one season's treatment.

The cost of the full treatment for the season was about 33 cents per tree. It is scarcely necessary to say that complete destruction of the ants would not bring about these results, nor did the ants in any degree prevent their attainment.

EXPERIMENTS IN CONTROLLING THE ARGENTINE ANT.

POISONING TESTS.

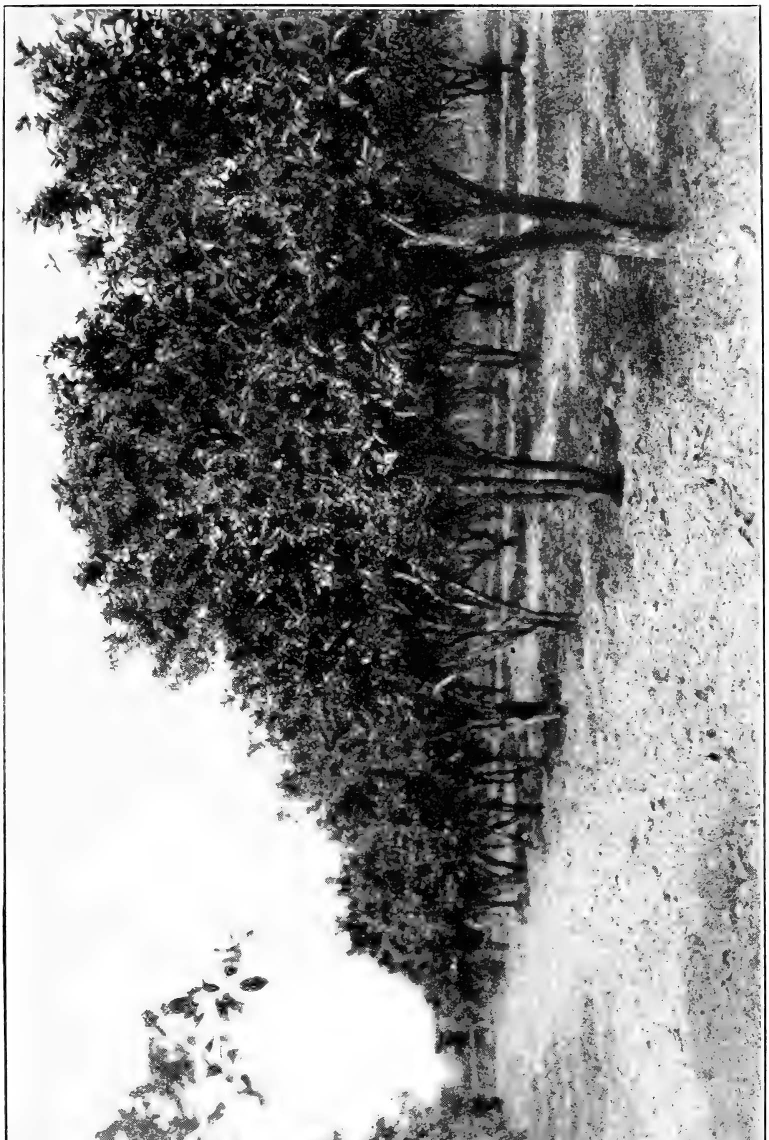
In the poisoning work conducted against the Argentine ant in Louisiana the following 16 poisons were tested: Strychnine sulphate, potassium cyanid, oxalic acid, arsenic trioxid, lead arsenate, Paris green, tartar emetic, oxid of antimony, mercuric chlorid, mercurous chlorid, copper sulphate, sulphate of iron, chrome alum, sodium arsenite, chloral hydrate, powdered extract of belladonna. As 14 of them were given a thorough trial at three different strengths in the field, and 20 further tests were made on imprisoned colonies, there were 62 experiments in all.

Methods of Conducting Poisoning Tests.

The receptacle used for the poisoned sirup was a deep-shouldered fruit jar of the type illustrated in Plate IV, with a tin lid with rubber band attached. A single entrance hole for the ants was punched in the center of the lid. To aid the ants in reaching the sirup, a piece of sponge was put into each jar. Scrap or waste sponges entirely suitable for this use may be purchased at wholesale drug stores for about 25 cents per pound.

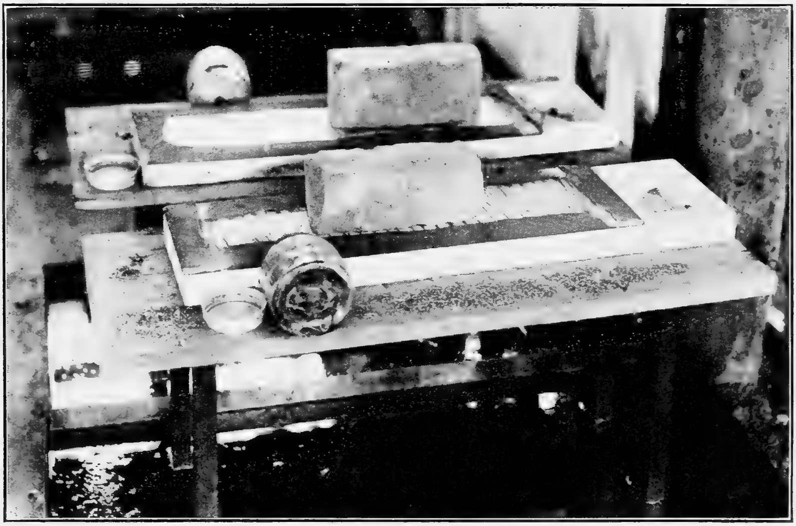
Upon beginning to forage at the poison, the ants would be traced to their nest and the location and size of the colony recorded, after which it would be watched and the effect of the poison noted. A definite amount of sirup, usually 4 or 8 ounces, was placed in each jar, every time, and the amounts taken by the ants thus learned.

In poisoning tests on imprisoned ants each colony was confined to a low table supporting a three-celled Janet type plaster of Paris formicary, furnished with vent holes covered with bronze gauze. The ants were allowed to roam at will on top of the formicary and the 4-inch margin between the sides of the formicary and the edge of the table. (See Pl. IV.) To prevent ants from leaving the tables, the latter were placed in shallow galvanized-iron pans about 8 inches wider and longer than the table tops, containing a lubricating oil costing from 15 to 25 cents per gallon. The advantages of this oil were the extreme slowness with which it evaporates, its lack of an odor which might disturb the ants, and its nondrying property. Fresh sirup, cockroaches or other meat, and water were always at



EXPERIMENTAL ORANGE GROVE AT OLLIE, LA., AFTER TREATMENT.

Note the poor shape and small top of the trees resulting from neglected pruning and too close planting. The black spots on the crown of the second and fourth trees are wounds caused by the "sore shin" disease. (Original.)



INTERIOR OF FORMICARIUM.

Type of formicary used in ant poisoning experiments, and method of preventing the escape of ants by resting tables in shallow pans of lubricating oil. (Original.)

hand on the table, in addition to the poison, in order to approximate field conditions as nearly as possible. With this apparatus and method of feeding, ant colonies have been kept in a state of health for nearly two years. In some cases, where the ants are confined for prolonged periods without flesh food, they feed upon their own eggs and young.

Summary of Results of Poisoning Tests.

In conducting tests on nonimprisoned ants, difficulty was experienced in determining the effect of the poison upon the ant colony. Desertion of the nest may mean that the ants have been destroyed, that the poison has merely impelled them to move, that they have moved from need of better quarters, or that they have discovered more abundant and suitable food elsewhere. The colony may move slowly from the immediate neighborhood of the poison, but its scouts continue to hang about the latter indefinitely. It may remain where it is and follow the original trail near the poison without visiting it. Slow migration may occur, giving the impression that the colony is being destroyed, when such is not the case. From 26 to 298 days were required to bring out the results. If the poison dosage is too strong, the ants will leave it before much harm befalls them; if so weak as to assure continuous feeding, its action is extremely slow. The amounts of poisoned sirup consumed by the ants in field tests varied from as low as 0.04 ounce per day over a period of 189 days to as high as 1.2 ounces per day for 296 days. Dead worker ants were found in or near the poison jars only in the case of three of the poisons, viz, strychnine, potassium cyanid, and arsenic. Large numbers of dead ants occurred often only at the jars containing potassium cyanid.

The poisons selected for a final testing upon imprisoned colonies were strychnine, potassium cyanid, arsenic trioxid, lead arsenate, mercuric and mercurous chlorid, tartar emetic, sodium arsenite, chloral hydrate, and belladonna. The first symptoms of poisoning shown by the imprisoned colonies are a strong desire on the part of the workers for water and assiduous cleansing of the body, particularly the jaws. An ant will commonly regurgitate a dose of poison, and a sister worker will cleanse her distended jaws with great thoroughness, repeatedly going over them with the mandibles and tongue. The next effect upon the colony is generally the death of some of the young, followed by a slackening, and finally a cessation of oviposition. The young then die rapidly, followed by workers, until all of both phases are dead. The queens then begin to do their own foraging, and finally succumb to the poison, at times not until several days after the demise of the last worker.

The poisons which came through both tests with the best record were:

(1) Chloral hydrate, 3 gm., to sirup, 120 gm.
(2) Sodium arsenite, 0.143 to 0.287 gm., to sirup, 120 gm.
(3) Arsenic trioxid, 0.125 to 0.250 gm., to sirup, 120 gm.
(4) Lead arsenate, 1.0 gm., to sirup, 120 gm.
(5) Tartar emetic, 0.525 gm., to sirup 120 gm.

By far the most rapid and successful of all was the chloral hydrate mixture.

Poisoning Ants in the Orange Groves.

Two experiments were conducted in an attempt to destroy the ants in orange groves by means of poisoning. One of these, in which the trees were not banded and weeds were allowed to flourish during the experiment, failed to have any appreciable effect upon the ants.

In the other one a plat of 237 orange trees was first completely isolated from the rest of the orchard by means of barrier ditches. All weeds and trash were then removed from the plat, and the trees all banded with an adhesive mixture, thus limiting the food supply for ants within the plat to the poison and a comparatively few rotting oranges, dead insects, and fiddler crabs. The ground in the plat was almost covered with a mass of ants, there being 250 "very large," "large," and "small" colonies, or more than one for every tree. The ants took the poison intermittently, attendance being abundant at certain jars at one time, at others the next, and attendance at the poison was no doubt greater than it would otherwise have been because of the scarcity of food.

The result of the poisoning and tree banding together was to reduce the ants after about four months to 2 "large" and 17 "very small" colonies. On ordinary inspection and comparison with the adjoining plat one would say that there were no ants left in the treated plat. The poison, in itself, was not a marked success, however, as cutting off the food supply had caused fully 75 per cent of the ants to migrate, as shown by the speed with which the first large disappearance of ants took place, and the frequent occurrence of thousands of dead ants on the water in the ditches.

USE OF TREE-BANDING MIXTURES.

It seems doubtful whether adhesive and other repellent mixtures to be applied to the trunks of the trees will ever be used extensively as ant barriers in Louisiana orange groves. Such barriers do not reduce the ant population and can not be considered as a positive means of control. When used on a large scale bands of this sort need more or less frequent inspection and renewal or respreading, and the cost of

maintenance would not be justified under present conditions by the increased crop returns.

In Los Angeles County, Cal., it appears that the citrus mealybug could be completely controlled in many cases merely by excluding the ants from the trees. Should that condition remain indefinitely, banding the trees would probably be as cheap a method of checking the mealybug as any other. At all events tree-banding mixtures will always have a use in protecting yard and ornamental trees, beehives, etc., from the ants. They may be used also to advantage in some cases in connection with poisoning and trapping the ants.

In an endeavor to discover an ant barrier of this nature which would be impervious to changes in the weather, and which would only require infrequent renewal or respreading, more than 20 mixtures were tested upon orange, fig, and other trees. Lack of space prevents including detailed results of the individual experiments, and only the general conclusions already published elsewhere[1] will be stated.

Adhesive Mixtures.

The most effective material of the adhesive type tested was made after the following formula:

Flowers of sulphur, part by weight	1
Commercial tree adhesive, parts by weight	6

All the lumps in the sulphur should be broken and the two ingredients thoroughly stirred together with a wooden paddle. The sulphur not only greatly prolongs the softness of the material, but appears to have a sufficiently repellent effect upon the ants to prevent them from bridging the bands with bits of trash or their own bodies. This mixture will remain effective in rainy, foggy, or exceptionally dry weather for from 3 to 5 months. If directly exposed for long periods to the sun, however, the surface becomes hard enough for ants to pass, and the bands should, therefore, be applied where the shade of the tree will protect them. This mixture must not be applied directly to the bark of trees, as it will be to some extent absorbed and may in time cause injury. It should be applied to tire tape or other waterproof material which has first been wrapped about the trunk.

Repellent Mercuric Shellac.

It is well known that corrosive sublimate has a strongly repellent effect upon the ants, and is the active ingredient in most, if not all, of the "ant tapes" found on the market, as well as of those watery solutions to be applied to household furniture with a paint brush.

[1] Horton, J. R. Some weather-proof bands for use against ants. *In* Mo. Bul. Cal. St. Comm. Hort., v. 5, p. 419–421. 1916.

It seemed desirable to give this chemical a thorough trial in the field, but it was necessary to devise a means of protecting the mercuric salt from rain. The ant tapes and liquids on the market were useless for outdoor work, because their value was quickly destroyed by moisture.

In original experiments performed by the writer it was found that the corrosive sublimate could be made impervious to water by dissolving this salt in an alcoholic solution of shellac. A considerable experimentation, in which both methyl and ethyl alcohol and various strengths of the mercury were used, resulted in the following formula, which was most satisfactory:

Corrosive sublimate	gm	20
Ethyl alcohol	c. c	60
Shellac	gm	31

The corrosive sublimate is first dissolved in the alcohol, then the shellac added, and the mixture shaken until all is dissolved.

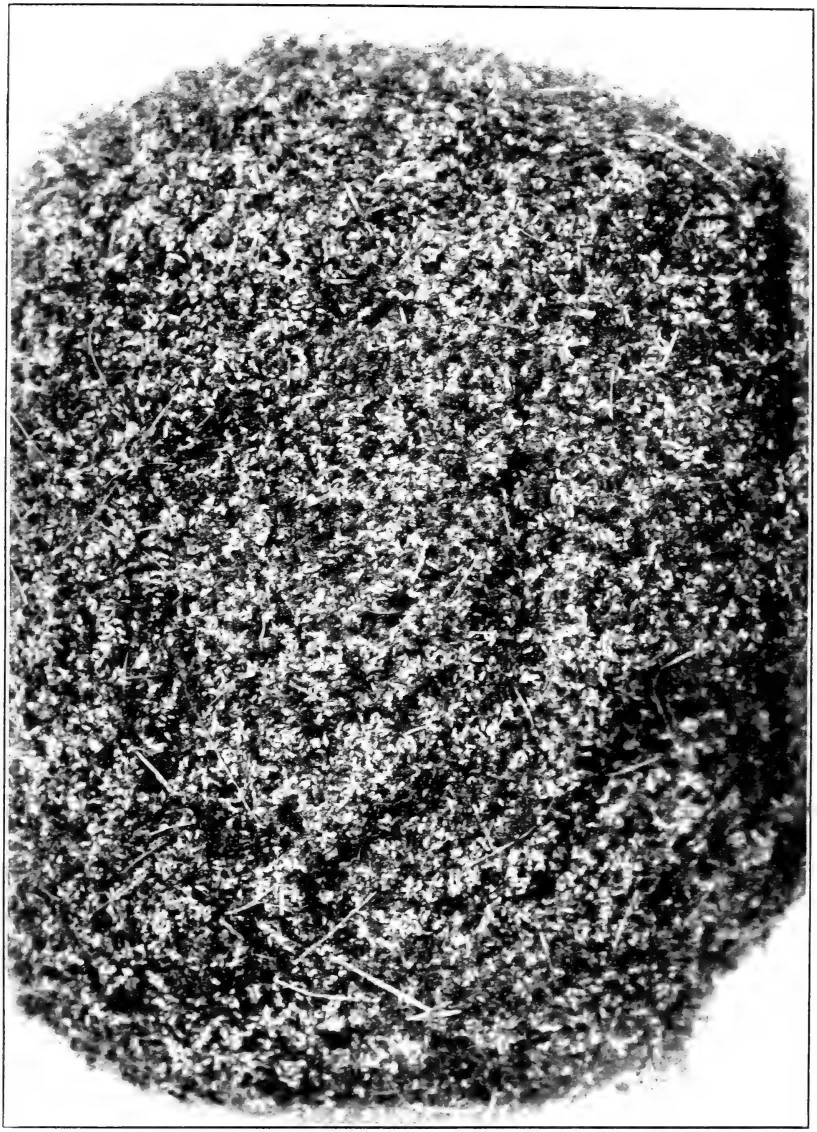
In the few tests made with this mixture in the field it proved effective against the ants for about two months under the most trying conditions. It is less effective, however, than the adhesive mixture previously described, and too expensive for use on a large scale. It must never be applied directly to trees, as it will quickly kill the bark clear through and ultimately destroy the tree. It may be used by first applying thickly to strips of cloth, or soaking the latter in the solution, and then allowing them to dry out thoroughly. This method is, however, too tedious and expensive for practical use.

Shellac solution of corrosive sublimate, made after the foregoing formula and painted in bands from 6 to 8 inches wide on the legs of tables, refrigerators, etc., where food is kept, ordinarily will keep the ants away for a year or more. The banding material will not long retain its strength when applied to metal surfaces, such as stove legs and galvanized-iron garbage pails.

There is considerable danger attendant upon the careless use of corrosive sublimate, but if the precaution is taken not to get it into a cut or abrasion, or into the mouth or eyes while mixing, there is nothing to fear from it. It is much safer to handle in the form of a shellac solution than in that of an ant tape, being applied with a paint brush and not requiring any direct handling whatever. Once the "paint" has become dry there is no chance for the corrosive sublimate to shake loose and get into food. In making ant tape, on the contrary, there is danger of splashing the solution into the face or of getting it into a slight cut on the hands in soaking and drying the cloth strips, and when these are applied the loose poison in the fibers of the cloth is a constant source of danger to young children and domestic pets.

TRAPPING THE ARGENTINE ANT.

Ant trap nest and fumigating cover used in destroying the Argentine ant in the orange groves of Louisiana. (Original.)



TRAPPING THE ARGENTINE ANT.

Mass of dead ants killed in one of the traps nests at Happy Jack, La. About one-third natural size. (Original.)

EFFECT OF CORROSIVE SUBLIMATE.

A poisonous emanation appears to be given off by the mercuric shellac band which is very injurious to the ants, as one example of the behavior of ants which have crossed it will illustrate. An ant attempting to cross one of these bands suddenly stopped when part way across and began to stroke the antennæ with the first pair of legs. It remained on the band about 1½ minutes, turning slowly about, stroking the antennæ, and drawing the legs between the mandibles. It then slowly retraced its steps off the band and moved aimlessly about for a time, often getting in the way of other ants. Soon one of these stopped and took hold of one of its antennæ. This made it active long enough to disengage itself, when it again became sluggish and wandered aimlessly. This continued as long as it was watched—about 10 minutes. Other ants, some of which were themselves sick, were trying to drag their dizzy fellows to a shelter. Most of the sick ants finally became very sluggish and many of them fell from the tree.

TRAPPING THE ARGENTINE ANT IN LOUISIANA.

By far the best and the only practical means of destroying the Argentine ant in the orange groves of Louisiana is by trapping. The discovery that the ants would collect in large numbers in boxes of decaying vegetation in winter was first made by Messrs. Newell and Barber, who described a method of destroying them based on this fact.[1] The method of trapping about to be described differs in several important respects, however, from that recommended by these gentlemen. It is based mainly upon the fact that a very slight rain at any season of the year will cause the ant colonies to come out of the ground, where most of them nest, and seek dry, sheltered places.

Effect of Rains Upon the Ants.

The favorite rainy-weather nesting places of the ants are under loose boards, piles of lumber, boxes, logs, sacks, and pieces of cloth, piles of bricks, piles of dead weeds, under and in the sides of buildings, etc. They also preferably seek high ground, and, other conditions being equal, the largest colonies will be found on the ditch banks and the high ground at the base of the trees. Just as foraging workers often complete a partial natural shelter found upon a tree or elsewhere by making walls of bits of trash, the ants often build elaborate structures of soil particles and trash under the loose boards and other shelters found on or near the ground.

The idea of using the traps about to be described was first suggested by the behavior of the ant colonies in an orange orchard in

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[1] Op. cit., p. 95–96.

which a poisoning experiment was being conducted. As the jars used would be partly filled with water every time it rained, a shelter was made for each of them out of two ends of an orange box nailed together in the shape of a gable. Soon after these covers had been laid, every one was found to harbor an ant colony which crowded it to its fullest capacity. Protection from the rain alone not satisfying the ants, they shut out the light and drafts by completely filling in the space between the jar and the top and ends of the cover with particles of soil. Each nest was no doubt ideal from the ants' point of view. Each was honeycombed with galleries of all shapes and sizes, ramifying in every direction. Any desired degree of moisture could probably be had in these galleries, those nearest the top being driest, and those directly on the surface of the ground most humid. The occupants would only need to move to underground quarters should prolonged dry weather occur. Each of these "ant castles," as they might be called, was perfectly protected from rain by a good pine roof. On removing the roof and looking into the galleries, thousands of eggs, young, and queens were revealed. Many solid masses of young and eggs as large as a hen's egg could be collected in these shelters. It was very evident that the ants could be much more rapidly destroyed when gathered together in this manner than by the tedious and unsatisfactory method of feeding them poison.

Protection from rain and drafts, good drainage, and darkness being the principal nesting requisites of the ants, it appeared that these requirements could best be met by a box with a roof. It was also found that ants could be induced to mass more thoroughly in numerous comparatively small colonies than in a few extremely large ones. A small covered box-trap was, therefore, given a trial, 15 of them being used in the first test. This was so satisfactory that it was followed by a large-scale experiment in which over 400 traps were used.

Description of Ant Traps and Fumigating Covers.

The first traps (see Pl. V) were made of $\frac{7}{8}$-inch cypress; but sap pine proved to be just as good and was cheaper. Each trap consisted of the following 9 pieces: Two sides, 12 by 12 inches; 2 sides, 10 by 12 inches; 1 bottom, 10 by 10 inches; 2 top pieces, 8 by 12 inches, and 2 pieces of triangular molding 12 inches long. First the smaller sides and bottom are fastened together with rosined nails or screws to prevent warping, then the larger sides added. The top pieces are fastened together in the form of a gable, with a tight joint, this roof being set loosely on top of the box. The pieces of molding are nailed across the inner side of the roof where it touches the top of the trap to hold it in place.

Covers to keep the gas in while fumigating are made of 28-gauge galvanized iron, each consisting of one piece 38 inches by $13\frac{1}{4}$ inches,

bent into two right angles, forming two sides and the top, and two pieces $13\frac{1}{4}$ by $13\frac{1}{4}$ inches, forming the other two sides. The edges of the latter two pieces are folded inwardly over those of the first piece and hammered tightly together. Covers with soldered, instead of hammered, seams are preferable, however, unless the latter are very well made. The completed cover should measure $12\frac{1}{2}$ by $12\frac{1}{2}$ by $12\frac{1}{2}$ inches inside, leaving a margin of $\frac{1}{4}$ inch to turn down all around the outside to reinforce the open edge.

Results of Ant-Trapping Experiment.

The experiment, the results of which are about to be briefly stated, was conducted in a block of approximately 19 acres[1] of bearing orange trees completely overrun with ants, located at Happy Jack, La. The traps, numbering 415 in all, or about 22 per acre, were set April 21–22, 1914. A trap was placed on a slight elevation at the outer edge of the spread of every second tree each way, or one trap to each four trees. Tests of various kinds of filler had shown previously that the best for summer was dry grass and weeds; for winter, equal parts of decaying manure and dry grass and weeds. From the time of setting the traps until the first rain, about 56 days, the ants were nesting almost wholly at from 8 inches to $1\frac{1}{2}$ feet in the ground. Even after such a period of prolonged drought, however, a rain of about 0.2 inch, occurring June 18, 1914, was sufficient to drive them into the traps in large numbers.

Tests of different strengths of carbon disulphid and strong ammonia water as fumigants proved that 12 ounces per trap of the ammonia was satisfactory. The carbon disulphid, however, proved satisfactory at as little as 2 fluid ounces per trap, allowing the traps to fumigate for 1 hour.

The first fumigation was started June 23, at which time it was necessary to fumigate 334 of the traps, only those which contained large and complete colonies being disturbed. The second, third, and fourth fumigations were started July 21, August 26, and September 28, respectively, completing the summer's killing. A solid mass of ants, in all stages, nearly as large as a man's hat, was killed in each trap each time. The workers and even the queens were so numerous that it was entirely out of the question to separate and count them in any large number of the traps (see Pl. VI). The queens, however, were counted each time in one or two traps with an average killing, and in this way it was estimated that 1,161,323 queens were killed in these first four or summer fumigations, 600,000 in the first two, 295,895 in the third, and 265,428 in the fourth. All of the traps were

[1] All references to the acre are to the "square acre," not the "acre front."

full and fumigated the second and third times, and 404 of them the fourth time. The next five fumigations were started November 12, and December 4, 1914, and January 7, February 25, and June 7, 1915, the number of traps fumigated being 409, 403, 405, 305, and 21 at each respective fumigation. The number of queens killed in the last five fumigations was 34,765, 32,240, 55,080, 19,215, and 4,599, respectively.

Before undertaking the work, an agreement had been made between the officers of the Bureau of Entomology and the orange grove company by which that company was, among other things, to maintain open barrier ditches[1] around the treated block, and keep that block of the orchard in a state of clean cultivation at its own expense throughout the course of the experiment. Succeeding events, however, prevented the company, through no fault of its officers, from carrying out its part of the agreement. The result was that the ditches were not maintained, and weeds and trash remained in the orchard at all times; hence, many ants migrated into the block, often being traced directly to the traps, and other nesting places besides the traps were numerous. The persistent habit of the queen ants of forming small offshoot colonies along the worker's trails is at once the principal means of spread and a great safeguard to the species. In the interval from the second to fifth fumigations, from 41 to 46 trails of ants were found migrating into the orchards from the direction of the levee alone, at every examination. Many ants from outside the orchard were, therefore, killed in the traps, and the duration of the work was unnecessarily prolonged thereby. The record of ants killed at the various fumigations is given in Table VIII.

TABLE VIII.—*Results of ant-trapping experiment in an orange grove. Louisiana, 1914–15.*

Fumigation No.	Date of beginning.	Number of traps necessary to fumigate.	Estimated number of queen ants killed.	Fumigation No.	Date of beginning.	Number of traps necessary to fumigate.	Estimated number of queen ants killed
1	June 23, 1914	334	600,000	7	Jan. 7, 1915	405	55,080
2	July 21, 1914	415		8	Feb. 25, 1915	305	19,215
3	Aug. 26, 1914	415	295,895	9	June 7, 1915	21	4,599
4	Sept. 28, 1914	404	265,428				
5	Nov. 12, 1914	409	34,765	Total			1,307,222
6	Dec. 4, 1914	403	32,240				

[1] It should be noted that a ditch of this sort already occurred along each side of the orchard from front to back, being constantly necessary to drain off the surface water. It was only necessary to clean the weeds out of these ditches and deepen them a little, and excavate a short ditch across the front of the place. The ants were prevented from coming in at the rear by the marsh.

After the eighth fumigation, February 27, 1915, there was very decided reduction in the number of ants in the orchard, and the foreman of the place remarked that the ants were getting very scarce in the block. Only straggling workers occurred in a few of the traps from this time until the next fumigation, June 7. On March 25 examination of 30 orange trees revealed only one scout ant, and it was reported that there were no more ants about. A ranch hand said he had uncovered only three nests in plowing the entire block, while in a neighboring orchard (which had been treated for ants by the flooding method for three years or longer) he had raised so many he could not keep track of them. On the same date the ants were extremely numerous in the orange trees in an adjoining grove.

A further examination on April 16 showed ants to be present on only 1 in 40 trees, and then not numerous enough to form trails. *There were no ants at the blossoms or at the numerous aphids on the trees.* Some large umbrella trees, which usually had from six to eight large trails, were absolutely free from ants. In the house it was no longer necessary to isolate food supplies, beds, etc., from the ants, from which there was not the slightest further annoyance, as stated by both the foreman and his wife. In the upper portion of the same property, about 90 rows from the experimental block, on the contrary, the ants were running in heavy trails up all the trees and were numerous in the blossoms and at aphids.

After the February fumigation another was not warranted for about three and one-half months, or until June 7, when 21 of the traps contained sufficiently large colonies to seem to warrant their destruction. The killing of queens had been reduced from nearly 300,000 in each of the first three or four fumigations to less than 5,000, and, of course, all the other stages had been comparably reduced. The experiment was a complete success, for it reduced the ants to negligible numbers.

The following rough but not widely erroneous estimates will give an idea of the populousness of the ants in this orchard: The total estimated number of queens killed, as reference to Table VII will show, was 1,307,222. The workers and young must be estimated by volume. In the first four fumigations every trap fumigated contained fully one-half gallon of ants in all stages, and in each of the succeeding five nearly a quart. The total number of traps fumigated in the first four operations was 1,568; therefore 784 gallons, or about $15\frac{1}{2}$ barrels, of ants were destroyed. In the remaining five fumigations there were 1,543 traps; therefore about 385 gallons, or about $7\frac{1}{2}$ barrels, of ants were destroyed. The bulk of the ants destroyed in this work, therefore, would be almost great enough to fill twenty-three 50-gallon barrels.

Method and Cost of Fumigating Ant Traps.

It is recommended that not less than 25 traps per acre of 100 trees be used in ant trapping in the orange groves. There should also be 12 covers for each 100 traps. A trap should be placed near every other tree each way. For example, one near each of the first, third, and fifth trees in the first row, then similarly in the third, fifth, and seventh rows, etc. The traps should be located just under the outer spread of the trees, where they will not be in the way of the cultivator or so close to the tree that the latter will be injured by the fumigant. The distance from the trunk should be about 4 feet. They should be placed upon slight, level elevations made by throwing up and smoothing off a few shovelfuls of dirt.

The ants will be destroyed much faster if every part of the orchard, including ditch banks and the tree hills, is kept free from weeds, loose boards, boxes, sacks, etc. It is, of course, not recommended to plow and cultivate during the winter months, but the orchard should be kept clean during the summer. In winter the traps should be filled with damp but not wet stable manure and dry weeds, the manure occupying the lower half of the box. In summer the manure, which is used principally for its heat, may be omitted. It is important to keep the lids on the traps at all times, as they keep out the rain, a very essential condition, darken the nest, and in winter help to retain its warmth.

When the trap is full of ants and ready to fumigate the lid is thrown off, 2 fluid ounces of carbon disulphid poured in, and the cover quickly slipped on, the edges being banked with dirt to aid in retaining the gas. One man can do the work where the number of traps is small. Where the number of traps is larger they can be fumigated most efficiently by a crew of three men, one of whom measures and pours the liquid while the others remove the covers from fumigated traps, place them over those to be fumigated, and bank them with earth. A shovelful of soil tamped down at each side is sufficient. The traps must be allowed to fumigate for an hour. A crew of three men working continuously can handle 48 covers, removing them from one lot of traps and resetting them over the next in from 50 minutes to an hour. Two ounces of carbon disulphid will kill every ant in the trap and ants, worms, and sowbugs for 3 inches in the ground beneath. While the same trap filler may be used indefinitely, it and the traps should be given a thorough airing after each fumigation.

The figures here given on the cost of installing and operating the traps are based entirely upon the foregoing experiment conducted by the Bureau of Entomology. The cost of the traps, made of C-grade sap pine, all parts cut to fit, knocked down, was $0.23 each,

to which must be added an additional $0.08 for transportation and setting up, making a net cost of $0.31 each. The covers were made and delivered for $0.75 each. On this basis the first cost of traps and covers per acre would be about as follows:

25 traps, at $0.31 each	$7.75
3 covers, at $0.75 each	2.25
Net cost of traps and covers per acre	10.00

A crew of three have in practice fumigated 400 traps in $1\frac{1}{2}$ eight-hour days, their services, at the rate of $1.25 per day each, costing $5.62. The carbon disulphid at that time cost $10.75 per hundred pounds. On this basis the cost of fumigating per acre of 100 trees per time would be about as follows:

Cost of labor fumigating 25 traps, at $0.014	$0.35
Cost of fumigant, 25 traps, at $0.013	.325
Net cost of fumigation per acre	.675

SUMMARY AND CONCLUSIONS.

Most of the orange groves of southern Louisiana, with the exception of well-tended groves and seedling orchards, have been declining in the last seven or eight years. As a rule, maximum productiveness is reached at from 7 to 10 years of age, after which it diminishes, the actual crop loss up to 1914 being approximately 37 per cent of the known possible production. The principal cause of this decline of trees and loss of crop, which has been largely blamed upon the Argentine ant, is cultural neglect.

The part played by the ant in causing this condition has been exaggerated. The only direct injury done by the ant is to destroy a negligible number of orange blossoms. The ants do not attend the armored scales of citrus or secure honeydew from them, nor do they disseminate the living scales. They do, however, disturb the predatory enemies of these scales, preventing the destruction of as large a proportion of them as would otherwise occur. Nevertheless, the natural enemies of the armored scales do not prevent heavy infestation even in orchards free from ants. The ant can not prevent the control of the armored scales in Louisiana by spraying nor will it increase the cost of spraying. Destruction of the ants will not control these scales, and they must be controlled if orange growing in that State is to be made profitable.

Under present conditions the Argentine ant does not cause exceptionally severe infestations in the orange groves of Louisiana, even of those soft scales to which it is most favorable. The mealybugs have not been of importance as an orange pest in ant-invaded orchards during the years 1913 to 1915, partly due to the effective-

ness of natural enemies, especially certain internal parasites, partly to overcrowding of the trees by armored scales and white flies, and partly because of the poor physical condition of the trees.

In Los Angeles County, Cal., where the trees are kept free from other scales and vigorously growing, the mealybugs increase tremendously as a result of ant attendance. Ordinarily they are kept under complete control, where the ants do not occur, by their predatory enemies. In orchards where fumigation has been neglected and the trees become overcrowded with the black scale, the mealybug does not benefit so much from ant attendance, and infestation is much milder.

The fluted scale has never been found in the orange groves proper of Louisiana, and the part played by the Argentine ant in causing the outbreak of this scale at New Orleans in 1916 is not known. The occurrence of this outbreak, closely following the 1915 hurricane, suggests the probability that the insect was largely spread by this means. The fluted scale is unable, under present conditions, to thrive on the orange trees of southern California even under the heaviest ant attendance, apparently being held in check principally by the Australian lady-beetle (*Novius cardinalis* Muls.), the green lacewings, and the dipterous larva *Cryptochaetum monophlebi* Skuse.

While the black scale occurs in New Orleans under constant attendance by the Argentine ant, the ant has failed to bring it into prominence there, and not a single infestation or even a single specimen has been discovered in any of the orange groves of Louisiana. In California the black scale infestations often become very severe after a single season during which fumigation has been neglected. In two years' time the insect is capable of increasing from almost none at all to such extreme numbers as to occupy every suitable feeding spot on the trees which it infests. Attendance by the ant for a single season does not noticeably increase the infestation of the black scale in California, where it reaches a maximum whether the ant is present or not. The natural enemies of this scale are not numerous and effective enough to control it.

While exceptionally large numbers of the soft brown scale occur on certain host plants or parts of such plants under ant attendance in Louisiana, the natural enemies of this scale, especially the internal parasites, continue to hold it to insignificant numbers in the orange groves under present conditions. In Riverside County, Cal., this scale appears to have increased considerably in certain ant-infested orchards, but is generally controlled along with other scales by fumigation. In Los Angeles County both the soft brown and the citricola scales are scarce in ant-invaded as well as other orchards. The soft brown scale, however, is undoubtedly more numerous on cam-

phor and bottle trees (*Sterculia diversifolia*) and some other plants in sections of Pasadena where the ants occur than in sections where they do not.

There is reason to believe that the Argentine ant may be an active agent in the spread of diseases through its habit of visiting various parts of the tree, and particularly freshly made wounds, for the purpose of feeding. It appears to introduce gummosis and wood-rotting fungi in this way more rapidly than could otherwise be the case. It may act as a conveyor of diseases of bacterial origin, such as the citrus canker, by carrying the causal organisms about on its legs and body.

The control of the Argentine ant in Louisiana by the trapping method described in preceding pages is entirely practicable at a moderate cost. If ants are deterred by barrier ditches from entering the grove rapidly, five or six fumigations about a month apart should so reduce the worst infestations that annoyance from ants will cease. Thereafter fumigation of a few of the traps once in every three to six months will suffice to prevent further molestation. The estimated cost of reducing the ants from most extreme numbers to the few remaining where there is effective control would be about $6.03 per acre[1] for labor and fumigant, or not to exceed $16.03, including the first cost of traps and covers. It is believed that large sections of territory where the annual rainfall is heavy could be effectively and economically freed from ants by this method if all the members of the community would cooperate in the undertaking. Although the labor of ant destruction might be somewhat prolonged in cities because of the numerous buildings and other suitable nesting places, this method, it is believed, might be advantageously adapted to city use.

Destruction of the ants in Louisiana orange groves will not effectively control the armored scales, or the white flies and the rust mite, and would not pay for itself in actual crop increase. Regardless of the ants many run-down orange groves in Louisiana can be so improved by one season's thorough spraying and cultural treatment as almost to double their production. The success of certain orchards in southern Louisiana demonstrates that oranges can be profitably grown there if the trees are carefully selected and planted and the best-known cultural practices and methods of insect control followed. The growing of citrus is a business which is increasingly requiring thoroughgoing business methods, and this applies in Louisiana as elsewhere.

[1] The term acre as used in southern Louisiana means an acre along the river front by 40 acres deep, and should not be confused with the present use of the term, signifying 160 square rods.

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